行政院及所屬各機關出國報告

（出國類別：研究）

步態分析在復健醫學之應用

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出 國 人 職　稱：主治醫師
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步態分析在復健醫學之應用

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內容摘要：　[詳次頁]

摘　要

步態分析是近十年來運用高科技電腦在復健醫學上的一個成功範例。藉由最新發展之電腦的高運算、與多重功能的特點，它能將人體步行時肉眼不易看清之各項特質，客觀而精密地加以測量出來。這使得它在復健醫學領域裡，不管是對於腦性麻痺兒、腦中風、腦外傷、以及各種神經肌肉系統之疾患所伴隨的動作與步態異常，在輔助診斷與評估治療效果方面，皆佔據了十分重要的地位。

本人此次在美國進修，首先跟隨 Dr. Sutherland，在他的實驗室裡，見識到更為先進的步態實驗設備，也與實驗室同仁們研討了步態分析出來數據判讀的要領，還學到 Fine wire EMG 的操作技術，對於將來我們在國內推展步態分析的研究，將有甚大的助益。

在研究方面，我們嘗試將步態分析與復健領域裡的疼痛醫學，做了聯結性的研究。我選定的主題是纖維肌痛症(Fibromyalgia)的病人。纖維肌痛症是一種全身到處都疼痛的病症，常常還伴隨著焦慮、沮喪、失眠、胃腸不適...等症狀。這種全身性疼痛的病人，會造成怎麼樣的步態異常，臨床上還沒有人做過這樣的研究。我跟隨的指導教授 Dr. Russell，是纖維肌痛症這一方面世界知名的大師。在我們第一階段的研究裡，是收集纖維肌痛症病人腦脊髓液裡的各種神經化學物質(neurochemicals in CSF)，與正常人腦脊髓液裡的神經化學物質相互比較，找出哪一些神經化學物質可以將纖維肌痛症與正常的人正確地區分出來，所建立的區分公式為：$Log[y/1-y]= -7.156 +0.359[SP] +0.051[NGF]-0.067[5HIAA]$，它所達到的區別準確率為 90.6%。

臨床上，纖維肌痛症的病人症狀越嚴重，其所顯現出來的異常步態也越明顯，包括步伐長度較短、站立期(stance phase)較長、擺盪期(swing phase)較短、穩定度較差...等；其間的關聯性以及在臨床上的重要性，都是我們下一步所欲探討的重點。

目次

正　文

一、目的

(1) 瞭解目前世界上步態分析之最先進科技與研究趨勢

(2) 學習肌肉疼痛醫學(纖维肌痛症候群)的研究理論與方法

(3) 探討步態異常與肌肉疼痛的相關性

二、過程

步態分析在近十年來，逐漸成為國內研究的熱門課題。本(復健)部因地利之便，得到本校醫學工程研究所的大力協助，因此在步態分析的研究上，起步還算很早。本人在攻讀醫學工程碩士學位時，即以腦中風患者的步態分析為研究主題，所得到的研究結果也曾在日本、美國等國際學術會議上發表。然而，電腦科技的發展日新月異，新的技術與機器不斷推陳出新；在得知獲得教育部補助出國研究的消息後，遂決定出國研習最新的步態分析技術。在醫工所蘇方慶所長、骨科部揚俊佑主任、林啟禎教授的推薦下，我前往位於美國加州 San Diego Children's Hospital 裡，跟隨 Dr. Sutherland 從事步態分析的研究。

Dr. Sutherland 是一位骨科醫師，也是一位知名的步態分析大師。他在 Children's hospital 所成立的步態分析實驗室，幾乎是一個獨立的部門。在獨棟的建築裡，有動現流暢的掛號處、等候區、辦公室、研究室、以及空間寬敞的步態分析實驗區。Dr. Sutherland 顯然是一位相當懂得經營的企業家，據說這整

棟的建築與實驗的設備都是他用研究計劃所爭取之經費而來的；而整個實驗室的成員，包括骨科醫師、物理治療師、小兒科醫師、還有醫工的博士專家、電腦程式設計師...，真可謂是人才濟濟！ 印象頗深的是其中一位醫工背景出身的教授，其所主講的一場關於肌肉的演講裡，其精辟入裡的程度，連我們這些科班出身背景的 醫師，都自嘆弗如！除了這所實驗室的建築，其實整個兒童醫院的建築內部與外觀，都是專為兒童所設計的，實在是令人欽佩他們對於兒童的照顧，與對自己所從事之事務的專注。

最值得一提的是，利用此次研習的機會，見識到美國目前最新的步態分析儀器。步態分析基本上就是一連串複雜電腦運算出來的數據，它可以經由六架紅外線攝影機攝取貼在身體上各個特定解剖位置上的反光球，再將這些光點輸入電腦主機裡，經過複雜而冗長的運算過程，才能將人體各段肢體在三度空間裡的位置顯現出來。這種運算過程，如果是用我們復健部原有的步態分析儀器(Ortho Track 2.0)來做的話，一般都要三至四個小時，既耗時又辛苦！而 Dr. Sutherland 實驗室現在所擁有的儀器，是(Ortho Track 5.0)，運算速度極快！幾乎是在受測者步行的同一時間，步態分析的運動學(kinematic)影像數據也馬上呈現出來，真是達到所謂的 real time 的境界！令曾經飽受舊機器耗時苦頭的我，大為讚嘆而佩服！這種立即顯像的功能，可以讓病人或受測者在受測試的當時，馬上能夠得知自己步行的實際狀況，不必再等一兩天以上才能看到報告，臨床上實在有極大的便利！

在研習期間，剛好趕上他們實驗室舉辦的步態分析研討會，使我有機會和來自世界各地約五十幾位的學者，共同研習步態分析的數據判讀，以及豪針肌電圖(Fine EMG)的操作技術。豪針肌電圖目前在國內還沒聽過有人做過，對我來說還算是相當新鮮的技術。它是使用相當細微的電極針，經過特殊的技術穿刺皮膚植入肌肉後，就能夠一面活動肌肉，一面同時紀錄該肌肉的動態肌電圖(dynamic EMG)。這種方法得出來的動態肌電圖，不同於傳統方式在靜止狀態下所測得的肌電圖，可以讓我們瞭解肌肉在整個運動過程當中真正的運作情形，不僅對於分析步態時有很大的貢獻，在手外傷的肌肉重建復健方面也相當重要。希望回國後能儘早克服軟硬體方面的問題，早日應用這種技術來服務臨床的病患。

在研究主題的設定方面，由於之前曾做過腦中風患者的步態分析，而最近這幾年本科部在前主任洪章仁教授的指導下，在肌肉疼痛(尤其是肌筋膜疼痛症候群 Myofascial pain syndrome)方面的研究成果是有目共睹的，因此便思索著如何結合這兩者的專長來做一關聯性的研究。經過洪章仁教授的推薦，我來到了德州大學聖安東尼奧健康科學中心(University of Texas Health Science Center at San Antonio; UTHSCSA)，跟隨 Dr. I Jon Russell 從事纖維肌痛症候群(Fibromyalgia syndrome)的研究，希望能探討出肌肉疼痛患者在步態方面是否有什麼特定的異常步態。

Dr. Russell 是纖維肌痛症 (Fibromyalgia) 世界知名的大師，他本身是

Journal of Musculoskeletal Pain 的主編，同時也是 International Myopain Society 的主席。 Fibromyalgia syndrome 是一個全身性疼痛的症候群，它常伴隨著疲勞、失眠、全身酸痛、憂鬱、焦慮、排便與膀胱障礙...等多種症狀。雖然它多半是以肌肉疼痛為主要表徵，然而多年來的研究仍舊無法在肌肉組織裡找到任何病灶性的證據。近年來學界已逐漸將研究重點擺向中樞神經方面，各種與疼痛傳導有關的神經介質 (nociceptive neurotransmitters)，包括：serotonin、substance P、5 hydroxyindole acetic acid....，都已被證明在 fibromyalgia 患者的身上有不正常的數值發生。我的第一篇研究，是將 Dr. Russell 所收集的 300 多位 fibromyalgia 患者腦脊髓液(CSF)裡的各種神經介質，運用多變異項、複迴歸的統計方式，歸納出一個可以區分出 fibromyalgia 患者與正常人的神經介質多項式方程式。第二篇的研究主題，則是將臨床上用來分析 fibromyalgia 的十幾項臨床指標，運用因素分析(factor analysis)的方法，將這些臨床指標歸納分類為四個因素；再將這四個因素與第一篇研究所建立出來的方程式，做相關性的分析，以驗證這個方程式的區分 fibromyalgia 患者與正常人的準確度。這兩篇論文都已被第五屆肌筋膜疼痛與纖維肌痛症世界大會所接受，即將在今年九月初在美國波特蘭市(Portland)所舉辦的大會上做口頭報告式的論文發表。兩篇論文的題目分別是：Discrimination of fibromyalgia patients from normal controls using the levels of cerebrospinal chemicals. 以及 Correlations of clinical variables with cerebrospinal chemical levels among fibromyalgia patients and healthy normal controls。而纖維肌

痛症與步態分析的關聯性，將是我回國後接著展開的研究重點工作。

三、 心得

此次有幸能獲得教育部補助，到美國做為期一年的研習，不僅有機會見識美國這個做為世界超強國家的醫療設施與醫學研究，還有機會能長期浸潤在他們的生活文化裡，親身感受到這種促使他們成為朝氣蓬勃之世界一流大國的氣息，內心實在有著無數的感想與省思。今僅就幾點簡述如下：

(1).政治成熟、民主守法

美國是全世界民主國家的始祖，民主的素養相當高。我在美國研習期間，剛好遇到 2000 年美國總統大選，由於票數不相上下，最後在最高法院的裁決下，由喬治・布希獲得總統寶座。想想這種情形要是發生在台灣，不是又要聚眾抗議、紛爭不休嗎？美國人在政治上有這樣民主的素養，實在是植基於日常生活裡每個小地方的守法觀念；舉凡開車時的禮讓、遇到小學校車時要停車禮讓、超市與購票時的排隊習慣，大家就是自自然然地按照規定來做，不會有爭先恐後的情形發生。

(2).專本業、盡己職

在美國，不論是醫院裡的醫師、護士，或是大門的警衛、清潔員，總是可以看到他們衣著整齊，態度和藹親切。各行各業，不論職務大小，總是讓人感到他們對於自己的工作感到愉快而驕傲，這種愉快的感覺很容易讓別人感受得到，使得不管是員工或是客戶，在整個工作環境裡都能培養出一種愉快的氣氛。

雖然也有人批評美國人只注重表面的親切，彼此個人生活方面的私交則不像我們中國人這樣熱絡；而且想到台灣的地狹人稠，那種過度的人際交往所產生的競爭與冷漠，總是很難讓人在工作環境中感到有愉快的氣氛。雖然台灣客觀的環境很多地方不如美國，不過我們還是需要用心去鼓勵工作團隊(醫院)裡的每一個成員，以他們所扮演的角色為榮，再激發他們的敬業心，才能夠提昇整個工作團隊的氣氛。

(3).深入而執著的鑽研

在美國研習的這一年，看到不論是 Dr. Sutherlannd 或是 Dr. Russell，他們各自在其研究領域裡，投入的幾乎都是一輩子的心血與精力。 Dr. Sutherland 窮畢生之力，設立了世界知名的步態分析實驗室，組成了陣容堅強的研究團隊，每年都吸引各國學者前來研習。而 Dr. Russell 一生在 fibromyalgia 的鑽研，不僅在世界上佔有一定的知名度，現在還是 International MyoPain Society 的主席。他曾很大方地打開他的書櫃，秀出整櫃的文獻都是他這幾十年來的著作，真是令我嘆為觀止，深深地感受到：什麼時候我們才能寫出一書櫃自己的文章呢？經過這樣親身的相處，深切體會到一個被人家尊崇而看重的學者，他對於學問的追求是這麼樣的認真與執著，對於身為年輕一輩的我們，實在具有很大的啟發與鼓舞作用。

(4).對下一代的尊重

美國人對小孩子的重視是眾所週知的。此次研習全家同行，剛好也深刻地

體會到人家所說的〝美國是小孩子的天堂〞這一句話的意義。不管是商場上的玩具，或是電視裡的兒童節目，都佔有極大的比重。好的書店甚至闢有兒童專屬的圖書區，備有玩具與童書，可以讓小寶寶在那裡消磨一陣子。在生活上，美國人也非常尊重小孩子的權益，他們會徵詢小孩子的意見，而不像我們傳統的中國人是以父母的意見為意見。如果我們讓小孩子從小就有空間為自己來做選擇，並培養他們從小就為自己的選擇而負責，這不就是一種很好而且很成熟的教育嗎？這不就是民主教育的最根本所在嗎？

四、建議

(1) 本人此次能有機會獲得補助出國進修研習，不僅在學術研究與教學交流方面，獲得很大的學習與啟發；在生活的態度與見識方面，也得到很多的增長與擴展。希望政府與教育相關單位，能繼續支持補助出國進修與研習的計劃，以利國內學術研究的大幅提昇。

(2) 我國的研究環境與研究經費本來就比美國要差。此次出國，親身見識到國外豐沛的研究經費與完善的研究設備，誠摯地希望國內在這一方面能盡量有所改善。國內政經情勢在這一段時間裡有很大的變化，健保局的經費核負也大大地限制了教學醫院在研究經費上面的編列，因此想要在學術研究上與世界各國並駕齊驅，政府與教育研究相關單位非得群策群力來克服這些難題。

(3) 雖然美國樣樣都好，但還是比不上自己的家鄉—台灣好！期許自己能在回國後，盡量找機會將自己在美國所看到的，不管是做學問的態度與做研究的方法，或是生活上守法的習慣與教育子女的態度，擴散出去進而影響他人，使國內的民眾也能逐漸地培養出這些外國人所具備的優點，進而提昇我們整個國家的競爭力，與整個社會的生活品質。

(4) 建立學術是有價的觀念。美國的研究經費豐沛，雖然一大部分來自於政府的補助，但是也有一大部分來自於私人的捐助與學術單位自己的籌款。因此，我在美國參加的幾個研習會(workshop)，其費用皆相當昂貴。一方面他們有必須研修繼續教育學分的設計，一方面他們也不斷地推陳出新，來使上課的內容更具有吸引性。國內很多的醫學會議或研習會還是停留在免費或低學費的階段，對於醫學研究的推展還是有很大的阻力！希望有關的學術單位能共同來推展〝學術是有價的〞這個觀念。

附錄(一)

論文發表：Discrimination of fibromyalgia patients from normal controls using the levels of cerebrospinal chemicals

Discrimination of Fibromyalgia Patients from Normal Controls Using the Levels of Cerebrospinal Neurochemicals

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Keywords: Fibromyalgia, serotonin, substance P, nerve growth factor, logistic regression analysis.

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ABSTRACT

Objectives: To develop a formula, using only neuro-chemicals in the cerebrospinal fluid [CSF], which will discriminate fibromyalgia [FMS] patients from healthy normal controls [HNC].

Methods: An extensive bank of CSF samples collected from clinically characterized, medication-free, primary FMS [ACR 1990 criteria] and HNC was utilized. From that bank, demographically similar cohorts of FMS and HNC were selected. Measured in CSF were substance P [SP], nerve growth factor [NGF], and 5-hydroxy indole acetic acid [5HIAA], and others. Logistic regression analysis and discriminant analysis methods were used to identify variables that could contribute to distinguish FMS from HNC.

Results: The study sample included 28 FMS and 25 HNC. The FMS were 45.0 ± 8.8 years, 78.6% female, 53.6% Caucasian. Logistic regression analysis and discriminant analysis methods both revealed that the CSF neurochemicals with significant regression and discriminant coefficients were: SP, NGF and 5HIAA. The best formula developed by logistic regression was found to be:

$$\log\frac{y}{1-y} = \mathbf{-7.156 + 0.359[SP] + 0.051[NGF] - 0.067[5HIAA].}$$

This formula distinguished FMS from HNC with an accuracy of 90.6%, which was better than the accuracy by discriminant analysis [83.0%]. Logistic probability scores correlated with the tender point index [TPI] .77 whereas discriminant function scores correlated with TPI .64.

Conclusion: Using only the concentrations of three CSF neurochemicals, a formula was developed which was able to distinguish FMS from HNC. Its "diagnostic"

accuracy was comparable to that of the clinical criteria [ACR 1990] used to diagnose the FMS group. This finding provides a new tool for the study of patients with FMS. In addition, it adds to the confidence that FMS is a clinical disorder in which there are objective neurochemical abnormalities.

INTRODUCTION

Fibromyalgia syndrome [FMS], now a well-recognized condition, is the third most common clinical disorder confronted with rheumatologists in their clinics (1). The prevalence of fibromyalgia in the general population was estimated to be 2% (2). Eighty to ninety percent of patients were female, and the peak age was 30-50 years (2,3). Based on a history of chronic widespread musculoskeletal pain for more than 3 months and the presence of at least 11 of 18 tender points at discrete anatomic locations, the 1990 American College of Rheumatology [ACR] published criteria (3) for the classification of FMS with high sensitivity [88.4%] and specificity [81.1%]. While soft tissue pain is the primary symptom of FMS, there are some other important features, but not required by the ACR criteria, including sleep disturbance, fatigue, headache, irritable bowel syndrome, interstitial cystitis, paresthesias, cognitive deficits, depression and anxiety.

Up to date, the definitive etiology of FMS has not been completely understood. Although the skeletal muscles where FMS patients complained of pain were at first considered to be the primary problem, delicate histological and ultra-structural study has failed to identify any abnormality in skeletal muscles (4). On the other hand, the characteristic feature of the diffuse pain in FMS is proposed to have a central, systemic and neurochemical pathogenesis. The proposition comes from several clinical observations, such as: the tender structures are not only limited to the muscle, but also include tendons, ligaments, bursae and etc; even the so-called "control points" ["non-tender sites"] are highly correlated with the anatomically defined "tender points" on the severity of tenderness; FMS patients have consistently disclosed a lower than normal pain

threshold by dolorimetry. The lower than normal pain threshold, as "allodynia" defines, is a clinical situation in which pain results from a stimulus which should not normally be painful (5). Thus, FMS can be defined mechanistically as "chronic widespread allodynia" (6). Since allodynia has been demonstrated to be induced by abnormalities in the absolute concentrations of, or relative availability of nociceptive chemical neurotransmitters in animal study (7), it is rational to redirect the focus of FMS from the local tender points to the central nerve system in FMS patients by examining its neurochemicals for better validation of the pathogenesis of FMS.

One of the first neurochemicals to be implicated in FMS was serotonin [5HT]. Through its effect on the release of substance P [SP] from primarily afferent neurons, 5HT is known to be a down-regulator of pain perception. It also influences the magnitude of substance P's effect on the ascending dorsal horn neurons of the spinal cord (8-11). Moldofsky and colleagues were the first to suggest that 5HT might be involved in the pathogenesis of FMS (12,13). They found a correlation between plasma tryptophan [TRP, the essential amino acid precursor of 5HT] and the severity of the clinical symptoms. Russell (14) had summarized the cumulative evidence that the serum concentrations of both TRP (15,16) and 5HT (17,18) were significantly lower than normal in FMS patients. However, it is very difficult to directly demonstrate 5HT deficiency in the brain, even in the cerebrospinal fluid [CSF], of FMS patients with current technology due to its limited sensitivity (19). On the other side, it has been possible to measure CSF levels of TRP, 5-hydroxytryptophan, and 5-hydroxy-indole acetic acid [5HIAA] (20-22). These three molecules are in the metabolic sequence by which TRP is first converted to 5-hydroxytryptophan, then to 5HT, and then to its final

excretion product 5HIAA. All are low, or borderline low in the CSF of people with FMS. With the additional findings that CSF levels of both 3-methoxy-4-hydroxyp-henethylene glycol [MHPG, a metabolic product derived from norepinephrine] and homovanillic acid [HVA, the terminal product of dopamine metabolism] being significantly lower than normal in FMS (20), it is indicated that there may be a major disturbance [a down regulation of several biogenic amines mediators] of brain neurotransmitter metabolism in FMS. More detailed and comprehensive researches for abnormal neurochemicals in CSF of FMS patients are warranted.

There are also many other neuropeptides being studied to reveal their relationship with "widespread allodynia" in FMS patients. In 1988, Vaeroy and colleagues (23) were the first to recognize that substance P [SP] was significantly elevated in the CSF of FMS patients compared with control subjects. Increased concentration of nerve growth factor [NGF] in the CSF of primary FMS patients was also noted in a recent study (24). Other related neuropeptides under investigation include calcitonin gene-related peptide [CGRP] (25), met-enkephalin-arg-phe (26), dynorphin A (27), ...etc. While investigators are continuing to search other neurochemicals that are related to the pathogenesis of FMS, the question that which of these neurochemicals are important in discriminating FMS patients from healthy normal controls [HNCs] still remains unanswered. Yunus et al (28) first used multivariate analysis to demonstrate that a combination of several biochemical parameters could better classify FMS patients and HNCs than an individual test alone. However, they only focused on plasma amino acids, plasma and urinary catecholamines, but rather CSF neurochemicals. Since it has been proposed that the pathogenesis of FMS is related to the interaction of multiple neuroendocrine-immune factors, we believe

the multivariable interaction relationship also exists among the various CSF neurochemicals. Therefore, the objective of this study is, using only CSF neurochemicals, to develop a multivariable formula to reveal which of these neurochemicals will better discriminate FMS patients from healthy normal controls [HNC]. The correlation between the formula and the tender point index [TPI] was also measured.

MATERIALS AND METHODS

Participants. Over the past several years there have been over 330 individuals recruited into our FMS study database through a standard protocol. Among them are over 156 patients with the diagnosis of primary FMS, which met the American College of Rheumatology [ACR] 1990 classification criteria for FMS (3). They have provided their demographic characteristics, medical history, details about the features of their FMS symptoms, etc. The healthy normal control [HNC] group comprised 57 healthy individuals who did not have symptomatic musculoskeletal pain and who did not meet the classification criteria for FMS. The ethnicity of the enrolled subjects will reflect the ethnicity of the community with efforts to match demographically to the FMS patient group. Informed consent to perform assays on the samples was obtained at the time of sample collection. The sample collection process was approved by the Institutional Review Board of the University of Texas Health Science Center.

Data collection. All medications known to reduce the severity of FMS symptoms were discontinued for at least 14 days [>5 half lives for most drugs] prior to the sample collection. The lumbar puncture for CSF samples was collected on FMS patients and HNCs under sterile conditions with the subject in the seated position. The procedures for neurochemicals assay were performed only after all of the standardization techniques have been completed. The neurochemicals measured in the CSF samples included: SP, NGF, MHPG, HVA, 5 HIAA, CGRP, neuropeptide Y, quinolinic acid, nitrate, nitrite, dynophin A, and antipolymer antibody. Tender point index [TPI] was used to represent the clinical pain measurement, which was calculated from the severity of discomfort

induced by 4 kg finger palpation pressure at each of the 18 defined tender points (29).

Statistical analysis. Statistical analysis was performed using SPSS for Windows, release 10.0.1.(30). Difference of the neurochemical concentration between FMS and HNC was assessed by Student *t*-test. Significance was set at P=0.05. To identify which variables could contribute to distinguish FMS from HNC, two statistical models for predicting group membership, logistic regression analysis and discriminant analysis, were employed to develop a distinguishing formula. The correlation between the clinical variable, TPI, and the obtained formula scores was also computed by Pearson Product-Moment method.

RESULTS

Although our database had CSF samples from 156 well characterized primary FMS patients and 57 HNCs, not every neurochemical such as CGRP, neuropeptide Y, dynophin A, ...etc. was yet measured presently in every CSF samples. Neurochemicals of interest for our study were SP, NGF, MHPG, HVA, and 5HIAA. To perform logistic regression and discriminant analysis, all the subjects must have available data in each of these variables. Because of these requirements, the initial pool of subjects was reduced to 28 FMS patients and 25 HNCs, who had data in all the analyzed variables. The mean age of FMS patients was 45.0 $\pm$ 8.8 years, 78.6 % of them were female, and 53.6 % were Caucasian. Data on demographic and clinical features were listed in Table 1.

In logistic regression analysis, we used the backward technique to determine which neurochemicals could be the better contributing components in a multivariable formula for discriminating FMS patients from HNCs. Among these 5 neurochemicals, MHPG was removed from the equation in step 2, and HVA in step 3 [Table 2]. The criterion for removal of predictor variables from the equation was default: POUT = 0.10. This means that significance of change when a predictor is removed from the equation must be $P < 0.10$ in order to keep this predictor in the equation. The results showed that SP, NGF, and

5HIAA were important components with significant coefficient for discrimination between FMS and HNC. The discriminating formula was found to be:

$$\log\frac{y}{1-y} = \mathbf{-7.156 + 0.359[SP] + 0.051[NGF] - 0.067[5HIAA].}$$

In this formula, it was apparent that SP was the most important components. The accuracy of this discriminant formula in distinguishing FMS from HNC was estimated to be 90.6%.

Discriminant analysis was also used to further validate the discrimination of these CSF neurochemicals. The result again revealed that SP, NGF, and 5HIAA were significant components, which was the same result as tested by logistic regression analysis. However, the accuracy of distinguishing FMS from HNC in the discriminant analysis was 83.0%, not as high as that of logistic regression analysis.

Τηε χορρελατιον βετωεεν λογιστιχ προβαβιλιτψ σχορεσ ανδ ΤΠΙ ωασ 0.77, ωηιλε τηατ βετωεεν δισχριμιναντ φυνχτιον σχορεσ ανδ ΤΠΙ ωασ 0.64.

DISCUSSION

Among 22 amino acids, Yunus et al (28) developed a multivariable formula showing that a combination of 7 variables [plasma histidine, methionine, tryptophan, norepinephrine, isoleucine, leucine, and urinary dopamine] could better classify FMS patients and HNCs than a single variable alone. The discriminant function they used provided the optimum sensitivity of 86% and specificity of 77%, with an accuracy of 81% (28). In contrast to plasma amino acid, our study focused on neurochemicals only in CSF. For further validation of the discrimination of these CSF neurochemicals, two statistical models including logistic regression analysis and discriminant analysis were used to predict group membership between FMS and HNC. Although both statistical models identified the same CSF neurochemicals, which consisted of SP, NGF, and 5 HIAA, to be contributing components in a multivariable formula for discriminating FMS patients from HNCs, the logistic regression analysis yielded a formula that provided better classification accuracy [90.6 %] than did the discriminant analysis [83.0%]. The correlation between logistic probability scores and TPI was comparable to that between discriminant function scores and TPI [0.77 vs. 0.64].

SP is an 11 amino acid neuropeptides which plays several important roles in the process of nociception (7). The levels of SP can be manipulated to induce allodynia in animal models (31). It is believed that SP may facilitate nociception by "alerting" or "arming" spinal cord neurons to incoming nociceptive signals from the peripheral. Released from activated, myelinated A-delta and C-fiber afferent neurons, SP randomly diffuses into laminae I and V [A-delta] and laminae II [C-fiber] of the spinal cord dorsal horn where it makes contact with its effector neurokinin-1 receptor. SP can also diffuse

out into the extracellular space and from there to the CSF, where it can be measured as CSF SP (32). While SP in the serum (33) (Russell et al, unpublished, 1994) and in the urine (Russell and Clauw, unpublished 1994) of FMS patients were found to be within normal range, the level of SP in the CSF of FMS patients was demonstrated to be two- to three-fold higher than normal controls (23,26,34), which is the most dramatic and consistent chemical abnormality found to date in FMS patients. Although there is evidence that SP can be slightly elevated in other painful conditions such as osteoarthritis (35), FMS is the only clinical disorder known to exhibit such profoundly elevated levels of CSF SP. Patients with a variety of neuropathic conditions were found to exhibit lower than normal CSF SP levels (36,37). The elevated CSF SP levels clearly distinguish patients selected by the ACR 1990 criteria (3) from healthy normal individuals. Age and gender had no influence on the measured CSF SP levels but minor differences related to ethnicity were noted (34). A recent study (38) using single-photon-emission computed tomography [SPECT] revealed that higher CSF SP in FMS patients correlated highly with a decrease in brain regional cerebral blood flow [rCBF] within the caudate nucleus and thalamus of the same FMS patients. The reason for this relationship is not yet clear.

Nerve growth factor [NGF] is a neurotrophin which is essential for the growth of peripheral nerves and perhaps spinal cord neurons during mammalian nervous system development (39-41). It apparently has no direct role in development of brain neurons. While developing neurons are dependent on NGF for survival during the neonatal period, especially sympathetic ganglia (42), adult neurons can survive without NGF (43,44). However, adult neurons remain responsive and plastic to NGF (43). Animal study

showed that a single systemic injection of NGF could result in mechanical and thermal hyperalgesia (45). Thermal hyperalgesia was also evoked in mice 24 h after intrathecal administration of NGF (46). One possible mechanism by which NGF may affect pain transmission is the stimulation of neuropeptide production, including SP and CGRP, in primary afferent neurons (40,47). Beside its ability to promote SP synthesis, NGF has also been reported to modulate inflammatory and immune responses (48,49).

Studies related to NGF in humans are still limited (50-52). CSF levels of NGF from newborns and children of up to 6 months have been found to be the highest level [mean 23 pg/ml] and then decreasing with age to almost undetectable levels in adult (50). It seems to rise in adults when there is neuronal stress or injury. For instance, elevated CSF levels of NGF were found in patients with brain injury (51) and in patients with multiple sclerosis (50). There is also evidence that viral and bacterial meningitis exhibit higher than normal CSF NGF levels (50). In multiple sclerosis, NGF levels in CSF seem to be chronically elevated but then rise to childhood levels with exacerbations of disease and fall back to the chronically elevated levels with remissions (50). By contrast, peripheral neuropathic disorders such as leprosy, diabetes mellitus, and nerve trauma exhibit lower than normal in the compromised neurons and the skin (52). Giovingo et al (24) recently used a modified 2 site enzyme immunoassay to measure the NGF levels in CSF of FMS patients compared to healthy controls. They concluded that CSF NGF levels in the FMS patients were significantly higher than that of controls (41.8 $\pm$ 12.7 pg/ml vs. 9.1 $\pm$ 4.1 pg/ml), which could theoretically have important implications concerning the role of neuropeptides in the pathogenesis of the allodynia of FMS.

There is convincing evidence to implicate 5HT deficiency as an etiologic factor of FMS (6,15,16,20). 5HT is a potent regulator of several CNS functions, which includes release of substance P, hypothalamic hormone secretion, deep sleep, and pain perception. Even small alterations in 5HT's availability might be expected to have rather profound effects. A total body reduction of 5HT metabolism among FMS patients is suggested by the finding of significantly lower than normal of 24 hours total urinary excretion of 5HIAA, the final metabolic product of 5HT (53). The CSF pool size of 5HIAA, as well as the CSF pool sizes of the other two 5HT metabolic molecules [TRP and 5-hydroxy-tryptophan] in FMS patients, were all found to be significantly lower than that in HNC CSF (20,22). These findings are only indirect evidences suggesting that something is amiss with 5HT body-wide availability in FMS patients. Unfortunately, the pool size of 5HIAA does not necessarily correspond to the turnover rate of 5HT, which would be the value of greatest interest. An alternative approach might be to measure the conversion of isotope-labeled TRP to labeled 5HIAA over a defined period of time in FMS and HNC.

In summary, a multivariable formula being capable of discriminating FMS from HNC was developed using only the concentrations of three neurochemicals [SP, NGF,5HIAA] in CSF. Its "diagnostic" accuracy was comparable to that of the clinical criteria [ACR 1990] used to diagnose the FMS group. This finding provides a new tool for the study of patients with FMS. In addition, it adds to the confidence that FMS is a clinical disorder in which there are objective neurochemical abnormalities. However. We can't predict the utility of the formula at this point but it may prove useful in predicting other biochemical directions that should be further explored in the central

nervous system for the pathogenesis of FMS.

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TABLES

Table 1. Demographic and clinical characteristics of study subjects

Variable	FMS (N=28)	HNC (N=25)
Age, years, ± SD	45.0 ± 8.8	37.1 ± 11.6
Sex (M:F)	6:22	13:12
Ethnic (C:H)	15:13	13:8*
TPI	26.5	13.9
SP	33.5	22.0
NGF	41.8	9.1
MHPG	33.6	38.3
HVA	46.8	41.5
5 HIAA	29.3	29.1

*

**P<0.05

FM: fibromyalgia, HNC: healthy normal control, C: Caucasian, H: Hispanic, TPI: tender point index, SP: substance P, NGF: nerve growth factor, MHPG: 3-methoxy-4-hydroxyphenethylene glycol, HVA: homovanillic acid, 5 HIAA: 5-hydroxy indole acetic acid.

Table 2. Logistic regression analysis of CSF neurochemicals for discrimination of fibromyalgia from healthy normal control

		B	S.E.	Wald	df	Sig.	Sig. of the change*
Step 1[a]	**SP**	.378	.133	8.055	1	.005	.000
	NGF	.052	.028	3.538	1	.060	.003
	MHPG	-.021	.038	.304	1	.581	.575
	HVA	.033	.045	.550	1	.458	.447
	5HIAA	-.095	.060	2.501	1	.114	.096
	Constant	-7.609	3.081	6.101	1	.014	
Step 2[b]	**SP**	.360	.128	7.913	1	.005	.000
	NGF	.058	.026	4.973	1	.026	.002
	HVA	.045	.041	1.206	1	.272	.249
	5HIAA	-.105	.057	3.408	1	.065	.042
	Constant	-8.173	2.983	7.505	1	.006	
Step 3[c]	**SP**	.359	.127	7.952	1	.005	.000
	NGF	.051	.024	4.351	1	.037	.004
	5HIAA	-.067	.043	2.417	1	.120	.094
	Constant	-7.156	2.701	7.020	1	.008	

SP: substance P, NGF: nerve growth factor, MHPG: 3-methoxy-4-hydroxyphenethylene glycol, HVA: homovanillic acid, 5HIAA: 5-hydroxy indole acetic acid.

a. Variables entered on step 1: SP, NGF, MHPG, HVA, 5HIAA.

b. Variable removed on step 2: MHPG.

c. Variables removed on step3: MHPG, HVA.

*. POUT=0.10

附錄(二)

Fifth World Congress on Myofascial Pain and Fibromyalgia

口頭論文報告資料

Discrimination of Fibromyalgia Patients from Normal Controls Using the Levels of Cerebrospinal Chemicals

Ta-Shen Kuan, Zarko Vukmirovic, Yangming Xiao, Richard Lawrence, I. Jon Russell

The University of Texas Health Science Center at San Antonio, San Antonio, USA

Fibromyalgia Syndrome

Chronic widespread M-S pain

Sleep disturbance, Fatigue, Headache, Depression, Anxiety, Irritable bowel syndrome, Interstitial cystitis, Paresthesias, Cognitive deficits.

1990 ACR Criteria

1. **History of widespread pain [more than 3 months]**
2. **At least 11 of 18 defined tender points**

Classification of Fibromyalgia Syndrome [FMS]
Sensitivity: 88.4% , Specificity: 81.1%

Pathogenesis of Fibromyalgia

- Lack of anatomic structural abnormality
- **Abnormality of nociceptive neurochemicals**
- **Serotonin ↓**
  plasma tryptophan (Russell, 1989)
  5-hydroxytryptophan (Russell, 1989)
  5-hydroxyindole acetic acid (Houvenagel, 1990; Kang, 2000)
- **3-methoxy-4-hydroxyphenethylene glycol & Homovanillic acid** (Russell, 1992)
- **Substance P ↑** (Vaeroy , 1988)
- **Nerve growth factor ↑** (Giovengo, 1999)

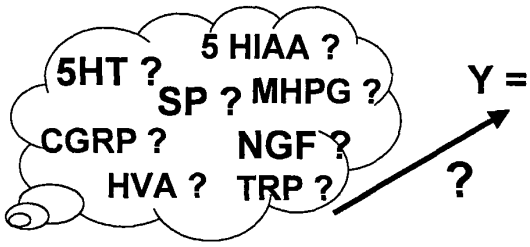
Multivariable Discriminating Formula

Plasma (P-) & Urinary (U-) Measures (Yunus, 1995)

D = 0.026 [P-histidine] + 0.103 [P-methionine] -
0.051 [P-isoleucine] - 0.046 [P-leucine] +
0.126 [P-tryptophan] - 4.184 [P-norepinephrine] +
0.006 [U-dopamine] - 1.994

- focused on plasma amino acids, plasma and urinary catecholamines
- better able to classify FMS from HNC than an individual test alone
- Sensitivity: **86%;** Specificity: **77%;** Accuracy: **81%.**

Objectives of This Study



$Y = aX + bY + cZ \ldots.$

ETo develop a **multivariable formula**, using only **CSF neurochemicals**, to reveal which of these neuro-chemicals will better discriminate **FMS** patients from healthy normal controls [**HNC**]

Materials and Methods

Materials and Methods

- **330 cases** from our FMS study database
  156 primary FMS (1990 ACR criteria)
  57 healthy normal controls [HNC]
- Neuro-chemicals measured in CSF samples included: **SP, NGF, MHPG, HVA, 5HIAA, CGRP, neuropeptide-Y, quinolinic acid, nitrate, nitrite, dynophin A, and antipolymer antibody.**
- Clinical pain measurement: **Tender point index [TPI]**

Statistical Analysis

- **Logistic regression analysis**
- **Discriminant analysis**
  Identify variables distinguishing FMS from HNC
  Develop a formula predicting group membership
- **Pearson Product-Moment method**
  Correlate formula scores and the TPI

Results

Demographic and Clinical Findings

Variable	FMS (N=28)	HNC (N=25)
Age (years. ± SD)	45.0± 8.8	37.1 ± 11.6
Sex (M:F)	6:22	13:12
Ethnic (C:H)	15:13	13:8*
TPI	26.5	13.9
SP	33.5	22.0
NGF	41.8	9.1
MHPG	33.6	38.3
HVA	46.8	41.5
5 HIAA	29.3	29.1

FMS fibromyalgia syndrome, HNC healthy normal control, C Caucasian H Hispanic,
TPI tender point index, SP substance P, NGF nerve growth factor,
MHPG 3-methoxy-4-hydroxyphenethylene glycol, HVA homovanillic acid
5HIAA 5 hydroxyindole acetic acid
* the other 4 is Black

Logistic Regression Analysis

of CSF Neruochemicals for Discrimination of FMS from HNC

		B	S.E	Wald	df	Sig.	Sig. Of the change**
Step1*	SP	.378	.133	8.055	1	.005	.000
	NGF	.052	.028	3.538	1	.060	003
	MHPG	- 021	.038	.304	1	**.581**	**.575**
	HVA	.033	.045	.550	1	458	.447
	5HIAA	-.095	.060	2.501	1	.114	.096
	Constant	-7.609	3.081	6.101	1	.014	

SP· substance P, NGF: nerve growth factor, MHPG· 3-methoxy-4-hydroxyphenethylene glycol, HVA. homovanillic acid, 5HIAA: 5 hydroxyindole acetic acid

* Variables entered on step 1. SP, NGF, MHPG, HVA, 5HIAA

Variable removed on step 2. MHPG.

**. POUT=0.10

Logistic Regression Analysis

of CSF Neruochemicals for Discrimination of FMS from HNC

		B	S.E	Wald	df	Sig.	Sig. Of the change**
Step2*	SP	.360	.128	7.913	1	.005	.000
	NGF	.058	.026	4.973	1	.026	002
	HVA	.045	.041	1 206	1	**.272**	**.249**
	5HIAA	- 105	.057	3.408	1	.065	.042
	Constant	-8.173	2.983	3 408	1	.006	

SP substance P, NGF nerve growth factor, MHPG 3-methoxy-4-hydroxyphenethylene glycol, HVA· homovanillic acid, 5HIAA 5 hydroxyindole acetic acid

* Variable removed on step 2 MHPG

Variables removed on step3 MHPG, HVA

** POUT=0 10

Logistic Regression Analysis

of CSF Neruochemicals for Discrimination of FMS from HNC

		B	S.E	Wald	df	Sig.	Sig. Of the change**
Step3*	SP	.359	.127	7.952	1	.005	.000
	NGF	.051	.024	4.351	1	037	.004
	5HIAA	-.067	043	2.417	1	.120	094
	Constant	-7.156	2.701	7 020	1	.008	

SP substance P, NGF: nerve growth factor, MHPG 3-methoxy-4-hydroxyphenethylene glycol, HVA. homovanillic acid, 5HIAA 5 hydroxyindole acetic acid.

* Variable removed on step 2. MHPG

Variables removed on step3· MHPG, HVA.

**. POUT=0 10

Multivariable Discriminating Formula

$$\text{Log } [y/1-y] = -7.156 + 0.359\,[SP] + 0.051\,[NGF] - 0.067\,[5HIAA]$$

Accuracy of discrimination of FMS from HNC:

Logistic regression analysis : **90.6%**

Discriminant analysis: **83.0%**

Correlation between

Logistic probability scores and TPI was **0.77**,

Discriminant function scores and TPI was **0.64**.

Discussion

Biochemical Pathogenesis of FMS

- ✓**Substance P [SP]** ↑ in FMS (Vaeroy 1988, Russell 1994)
  "alerting" or "arming" spinal cord neurons to incoming nociceptive signals from the peripheral.
- ✓**Nerve growth factor [NGF]** ↑ in FMS (Giovengo, 1999)
  affect pain transmission by stimulation of neuropeptide production, including SP (Kessler 1981, Lindsay 1989)
- ✓**5 Hydroxy-indole acetic acid [5HIAA]** ↓ in FMS
  implicate 5HT deficiency as an etiologic factor of FMS
  (Houvenagel 1990, Russell 1989)

Chronic widespread allodynia (Russell, 1996)

Conclusions

- A **multivariable formula**, using only three CSF neurochemicals [**SP, NGF,5HIAA**], is capable of discriminating FMS from HNC.
- Its **"diagnostic" accuracy** was comparable to that of the **clinical criteria [ACR 1990]** used to classify the FMS group.
- This finding provides a new tool for the study of patients with FMS.
- In addition, it adds to the confidence that FMS is a clinical disorder in which there are objective **neurochemical abnormalities**.

Correlations of Clinical Variables with Cerebrospinal Chemical Levels among Fibromyalgia Patients and Healthy Normal Controls

Ta-Shen Kuan, Zarko Vukmirovic, Yangming Xiao, Richard Lawrence, I. Jon Russell

The University of Texas Health Science Center at San Antonio, San Antonio, USA

Associated Symptoms

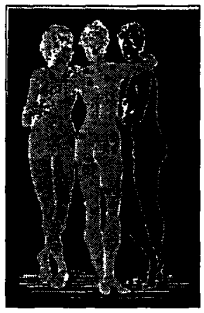
- Depression
- Anxiety
- Cognitive deficit
- Headache
- Dizziness, Syncope
- Chronic insomnia
- Fatigue
- Morning stiffness
- Chest wall pain
- Mechanic low back pain
- Myalgias, arthralgias
- Numbness, dysesthesias in hands and feet
- Irritable bowel syndrome
- Interstitial cystitis, frequency, urgency

(Russell, 1996)

Objectives

- to find the pattern of relationships among FMS clinical variables
- to determine the correlations between these clinical variables and the discriminant scores of the CSF neurochemical formula
- to test the utility of this formula in distinguishing FMS from HNC

Materials and Methods



Materials and Methods

- **28 primary FMS [1990 ACR criteria]**
  Age: 45.0 ± 8.8, Sex (M:F) 6:22
- **25 healthy normal controls [HNC]**
  Age: 37.1 ± 11.6, Sex (M:F) 13:12
- **CSF neurochemical formula for discrimination of FMS from HNC :**

Log [y/1-y] = -7.156 + 0.359 [SP]
+ 0.051 [NGF] – 0.067 [5HIAA]

Materials and Methods

23 clinical variables ranging from self-reported scales to pain threshold measures measured at the time of CSF collection

TPI : Tender point index

APT: Average pain threshold

PAININTE: Pain interference

LIMITACT: Limit of activity

CESD : Depression scale

ZUNG-D: Depression scale

HOWBAD: How bad

HOWTIRED: How tired

ANXIOUS: Anxious

STIFFNES: How stiffness

DURSTIFF: Duration of stiffness

DEPRESED: How depressed

FEELGOOD: Feel good

HEADACHE: Headache

ABDMPAIN: Abdominal pain

Materials and Methods

23 clinical variables ranging from self-reported scales to pain threshold measures measured at the time of CSF collection

HASSADD: Sum of scores for Hassles scale

STAIT: Stait of the Spielberger anxiety scale

TRAIT: Trait of the Spielberger anxiety scale

SEPAINAV: Self efficacy for controlling pain

SEFUNCAV: Self efficacy for function

SEOTHRAV: Self efficacy for other symptoms

HAQ: Stanford health assessment questionnaire

TTPPAL: Total number of tender points by palpation exam

Statistical Analysis

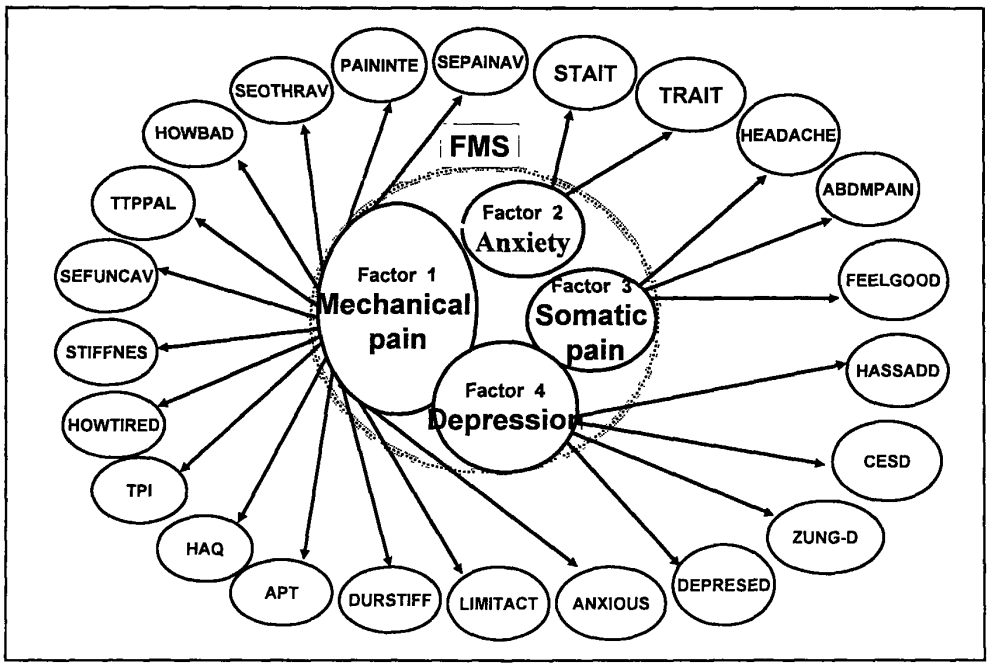
- **Exploratory Factor Analysis**
  to determine the pattern of relationships among variables
  to explain that pattern in terms of a smaller number of underlying hypothetical factors

- **Pearson Product-Moment method**
  to correlate these factor scores with the discriminant scores of our CSF neurochemical formula

Results

Pattern Matrix with Factor Loadings

Variables	1	2	3	4
SEPAINAV	-.878		120	
PAININTE	.871			- 153
SEOTHRAV	-.858		110	
HOWBAD	.802		220	
TTPPAL	.772		270	- 319
SEFUNCAV	-.754		321	
STIFFNES	.739		220	
HOWTIRED	.734		209	
TPI	.712		261	
HAQ	.686		- 181	269
APT	-.659		- 225	
DURSTIFF	.635			- 209
LIMITACT	.493	139	371	
ANXIOUS	.380	144	329	
STAIT	- 112		- 125	
TRAIT		.941		305
		.817		- 213
HEADACHE			.754	204
ABDMPAIN			.715	160
FEELGOOD	- 369		-.532	121
HASSADD		244	199	.843
CESD	323		223	.548
ZUNG-D	448			.472
DEPRESED	316	197	254	.454



Correlations of Formula with Factors

	Factor 1	Factor 2	Factor 3	Factor 4	Predicited probability	Discriminant scores
Factor score 1	1.000	.177*	.596**	.418**	.726**	.576**
Factor score 2	.177*	1.000	.154	.126	.366*	.496**
Factor score 3	596**	.154	1 000	.222**	.476**	.389**
Factor score 4	.418**	.126	.222**	1.000	.406**	.399**
Predicted probability	.726**	366*	.476**	.406**	1.000	844**
Discriminant scores	.546**	496**	389**	.399**	.844**	1.000

*0 05 **0 01

Discussion

Summary

- Factor analysis reduced 23 clinical variables into four dimensions [factors], which included: **mechanical pain**, **anxiety**, **somatic pain**, **depression**

- Each of factor correlated with the discriminant scores of the CSF neurochemical formula:

Mechanical pain	[r = **0.73**, p=0.01]
Anxiety	[r = **0.37**, p=0.05]
Somatic pain	[r = **0.48**, p=0.01]
Depression	[r = **0.41**, p=0.01]

Conclusions

- **Four dimensions were derived from selected clinical variables that distinguish FMS from HNC.**
- **Each dimension correlated with a formula derived from the concentrations of three CSF neurochemicals [SP, NGF, 5HIAA].**
- **These findings provide a new biochemical resource to the study of FMS.**
- **This study directly supports the hypothesis of an organic central nervous system pathogenesis for FMS.**

附錄(三)

Motion Analysis Laboratory in Children's Hospital, San Diego

Data Sheet and Normal Children Gait Curves

PATIENT HISTORY

NAME: _____ Date of Study: ___/___/____

Sex: M F Birthdate: ___/___/____ Age: ____ + ____ Ht: _____ Wt: _____

Referring Physician: _____

CHIEF COMPLAINT:

TREATMENT CONSIDERED:

BIRTH HISTORY:

P__ G__ Pregnancy problems: _____

Gestational Age: _____ Delivery: Vaginal Forceps C-section

Birth Weight: _____ Apgars: ___/___ Hospital: _____Time in NICU: _____

Complications: RDS PDA NEC Heart problems Jaundice (bili lights) Seizures

Abnormal CT scan Mech. Vent (length _____) Others: _____

DEVELOPMENTAL MILESTONES:

Sitting: _____ Crawling: _____ Walking: _____ Speech: _____

Vision (glasses) Hearing (aids)

CURRENT MEDICAL HISTORY:

Seizures Respiratory Problems Cardiac Problems

Learning Disability/Attention Deficit Disorder: _____

Medication: _____

Allergies: none or _____ Immunizations: up-to-date or _____

PAST SURGICAL HISTORY: - See green sheet

HISTORY OF PRESENT ILLNESS/PROBLEM:

PATIENT HISTORY – Page 2

CURRENT ACTIVITIES:

School: _____ **Grade:** _____ **Employment:** _____

Avocations: _____

AMBULATORY STATUS:

	Independent	*Community*	*Household*	*Therapy*
Endurance:	Household	1 block	2 blocks	Intermediate / Unlimited

Falls: ___/day **Assistive Devices:** Crutches Walker (rear / front)

Wheelchair/Stroller use: school long distances

Braces: (L/R/B) RGO HKAFO KAFO Art AFO Fixed AFO FRO Shoe inserts

THERAPY:

Physical Therapy: Where: _____ Frequency: _____/week

Occupational Therapy: Where: _____ Frequency: _____/week

Speech Therapy: Where: _____ Frequency: _____/week

Communication aids: _____

RADIOGRAPHS:

OBSERVATIONAL GAIT ANALYSIS:

CLINICAL IMPRESSIONS AND RECOMMENDATIONS:

MOTION ANALYSIS LABORATORY
SUMMARY SHEET

****

PATIENT'S NAME:_____ FILM NO:_____

DATE:_____ DIAGNOSIS:_____

AGE:___ ___ SEX:___ DATE OF BIRTH:__/__/___ HEIGHT:_____ WEIGHT:_____
Years Months Inches Pounds

REFERRING PHYSICIAN:_____

PREVIOUS STUDIES:_____

ORTHOPEDIC SURGERY AND DATES:_____

_____

_____

_____

BRACING:_____

PHYSICIAN ORDERS

Condition	*#1*	*#2*
MOTION		
FORCE		
EMG		
MOMENTS		
KNEE R L		
ANKLE R L		
HIP R L		
	R	L
TEKSCAN		

R	*EMG SURFACE*	*L*	*R*	*EMG FINE-WIRE*	*L*
	ADDUCTOR			ILIACUS	
	MED HAMS			RECTUS FEMORIS	
	LAT HAMS			POST TIB	
	VASTUS LAT				
	ANT TIB				
	GAST/SOL				
	PERONEALS				

X-RAYS:_____

OTHER TESTS:_____

STUDY NOTES: Condition #1=_____ Condition #2=_____

_____

_____

_____

_____

_____

PROCESSING INFORMATION: _____

_____

_____

_____

	Right	Left
KINEMATIC FILE NAME:	1._____	1._____
	2._____	2._____

COMMENTS: _____

MARKER SET: 15____ 21____ OTHER_____ FRAME RATE_____

	Right	Left
KINETIC FILE NAME:	1._____	1._____
	2._____	2._____

COMMENTS: _____

WIDTHS = Millimeters FORCE PLATE SETTING XY_____
Z_____

ASIS _____

GREATER TROCHANTER _____

	*Condition #1*_____		*Condition #2* _____	
	Right	Left	Right	Left
KNEE	_____	_____	_____	_____
ANKLE	_____	_____	_____	_____
FOREFOOT	_____	_____	_____	_____

SACRAL OFFSET _____ SACRAL OFFSET _____

ASYMMETRIC MEASUREMENTS:

	Right		Left	
Knee	Medial ____	Lateral ____	Medial____	Lateral____
Ankle	Medial ____	Lateral ____	Medial____	Lateral____

VCM: ASIS TO MEDIAL MALLEOLUS R_____ L_____
ASIS TO TROCHANTER R_____ L_____

COMMENTS:_____

_____

_____

_____

Children's Hospital, San Diego

Motion Analysis Laboratory

Name:	Age:	Date:	Film #

	Range of Motion		*Strength (0-5)*	
Hip:	Right	Left	Right	Left
Flexion				
Extension Supine				
Extension Prone (Staheli)				
Abduction with Extension				
Abduction with Flexion				
Adduction				
External Rotation (Prone)				
Internal Rotation (Prone)				
Comments:				

Knee:	Right	Left	Right	Left
Extension				
Flexion				
Straight Leg Raise				
Popliteal Angle				
Comments:				

Ankle:	Right	Left		
Dorsiflexion (knee 0°)				
Dorsiflexion (knee 90°)				
Plantar Flexion				
Inversion				
Eversion				
MMT:	Ant Tib			
	Post tib			
	Peroneals			
	EHL			
	EDL			
	FDL			
	Gastroc: Manual			
	Standing			
Comments:				

Neurologic Tests	*Right*		*Left*	
Deep Tendon Reflexes (1+to 4+)		*clonus*		*clonus*
Patellar				
Achilles				
Clonus (stretch ±)				
Babinski (±)				
Selective Control				
N=Normal G=Good M=Moderate P=Poor				
Confusion (Resisted ±)				
Ely (Fast±)				
Rectus Tightness (degrees)				
Comments:				

Torsional Alignment	*Right*	*Left*
Clinical Anteversion		
Thigh-foot Axis	Int/Ext	Int/Ext
degrees		
Transmalleolar Axis	Int/Ext	Int/Ext
degrees		
Comments:		

Trunk:

Physician:

Physical Therapist:

Children's Hospital, San Diego
Motion Analysis Laboratory

Name:	Age:	Date:	Film #

Special Tests	*Right*	*Left*
Trendelenburg		
Balance:		
Romberg		
Eyes Open		
Perturbation		
Gowers		
Tandem Walking		
One leg stance		
Ober		
Galleazzi		
Ortolani		
Pivot Shift		
Anterior Drawer		
Posterior Drawer		
Comments:		

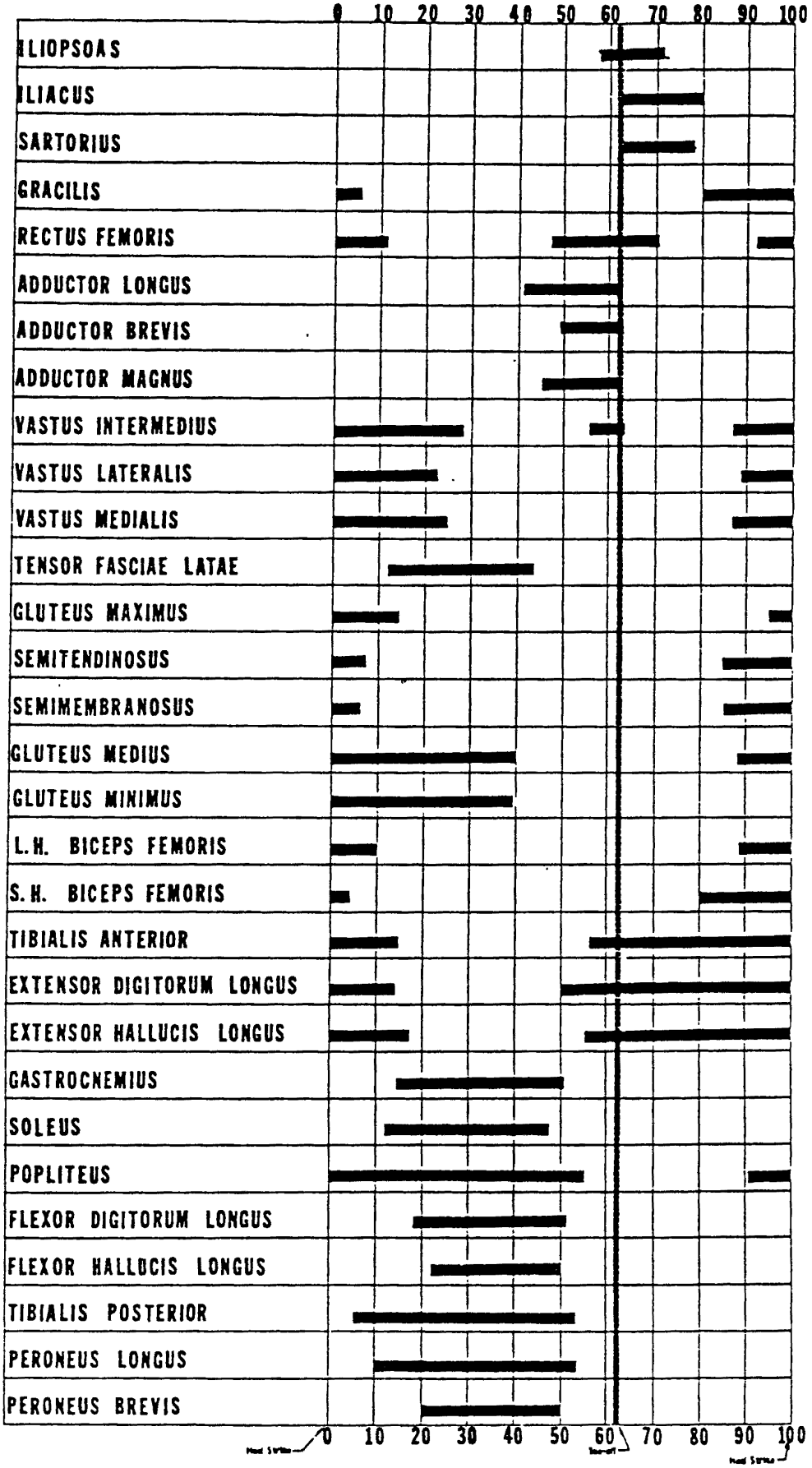
Clinical Measurements		
Height *(inches)*		
Weight *(pounds)*		
	Right	*Left*
Leg Length *(cm)*		
Asis - Medial Malleolus		
Asis - Greater Trochanter		
Blocks		
Assistive Device		
Type of Braces		

Additional Comments:

Physician:

Physical Therapist:

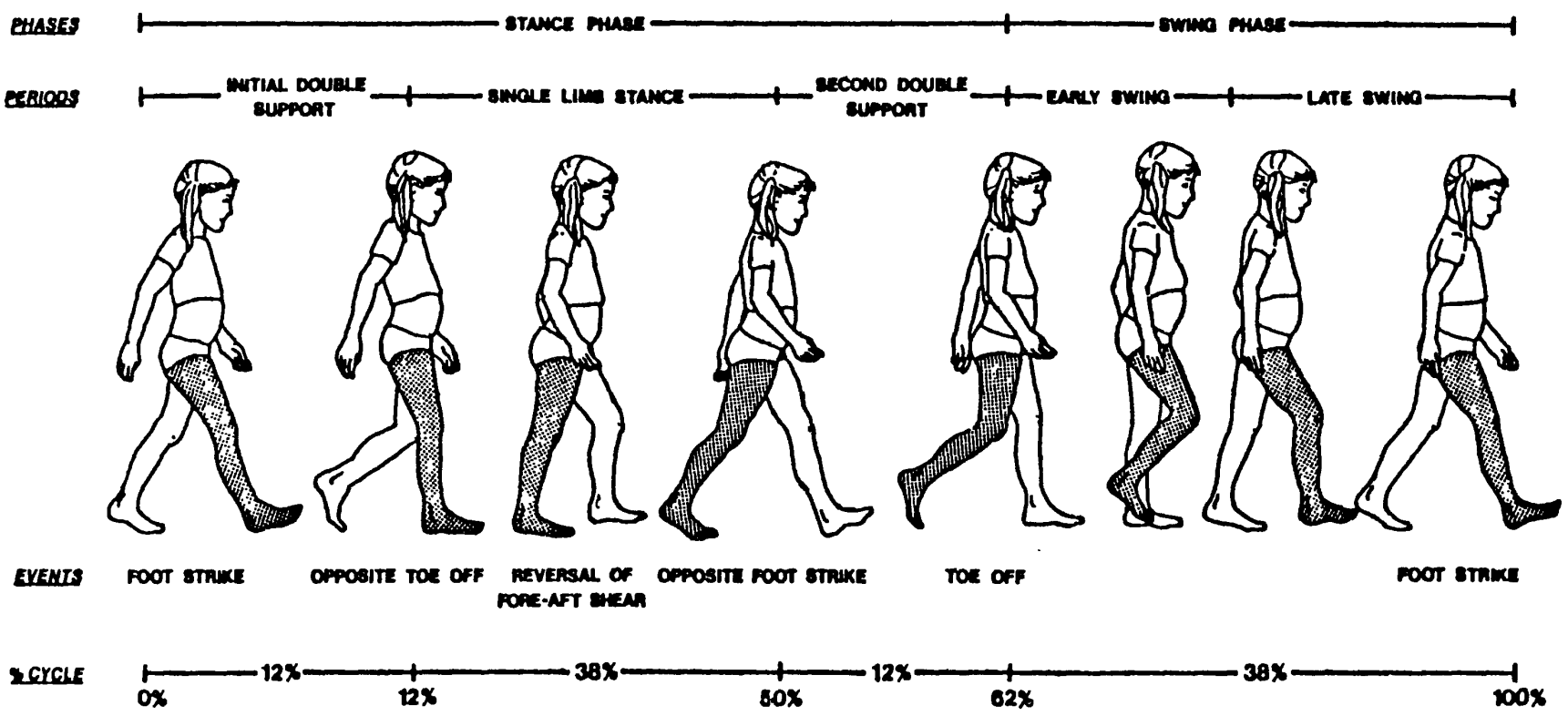
NORMAL ELECTROMYOGRAPHIC DATA



Analysis Laboratory
's Hospital
go California

CHILDREN'S HOSPITAL & HEALTH CENTER
MOTION ANALYSIS LABORATORY
SAN DIEGO, CALIFORNIA

TYPICAL NORMAL WALK CYCLE

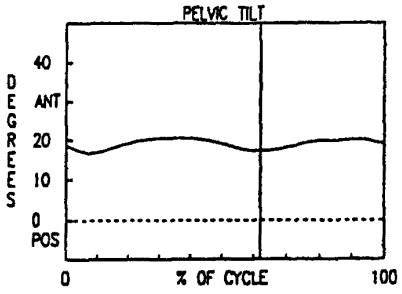


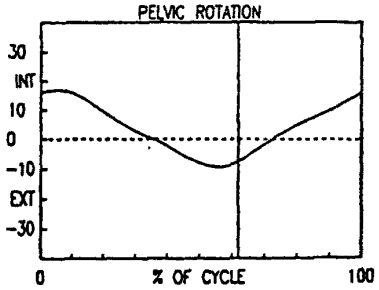
MOTION ANALYSIS LABORATORY
CHILDREN'S HOSPITAL & HEALTH CENTER
SAN DIEGO, CALIFORNIA 92123

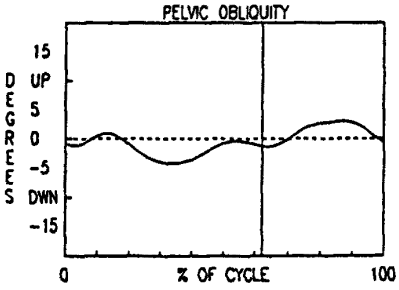
NAME:
DATE:
SIDE:
AGE:
DIAGNOSIS:
KEY:

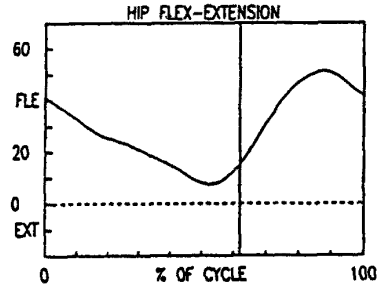
STUDY DATE	
SIDE	
OP TOE OFF (% CYC)	17%
OP FT STRIKE (% CYC)	49%
SNGL STANCE (% CYC)	32%
TOE OFF (% CYC)	67%
STEP LENGTH (CM)	22 cm
STRIDE LENGTH (CM)	43 cm
CYCLE TIME (SEC)	0.68 sec
CADENCE (STEPS/MIN)	176
VELOCITY (CM/SEC)	64
	n=51

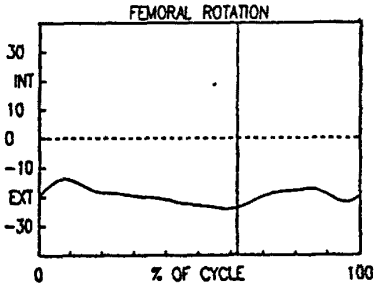
1.0 YEAR NORMAL ——

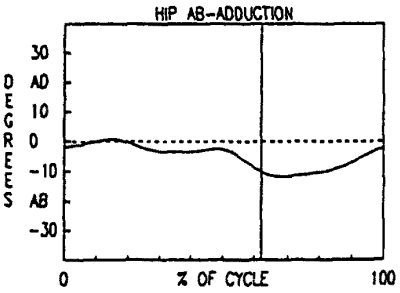


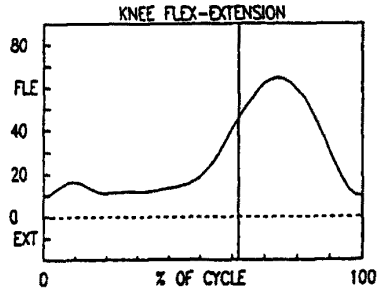


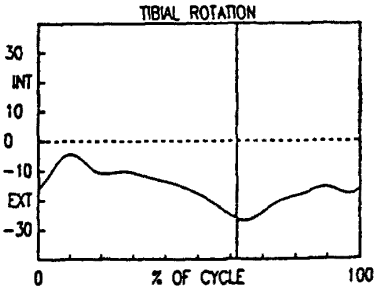


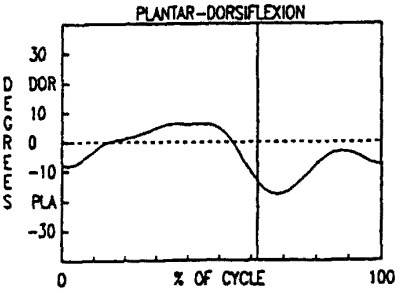


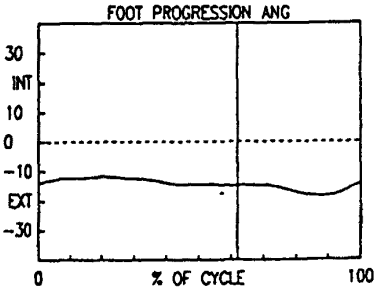












MOTION ANALYSIS LABORATORY
CHILDREN'S HOSPITAL & HEALTH CENTER
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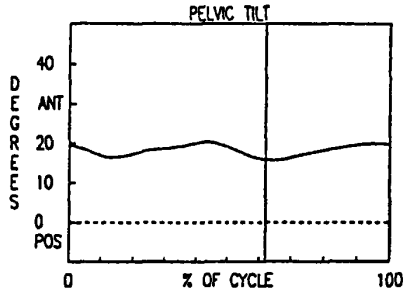
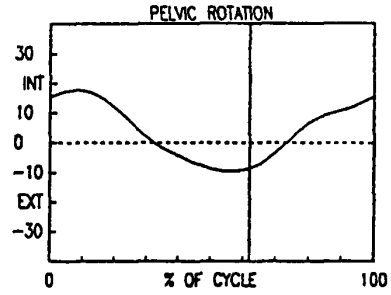
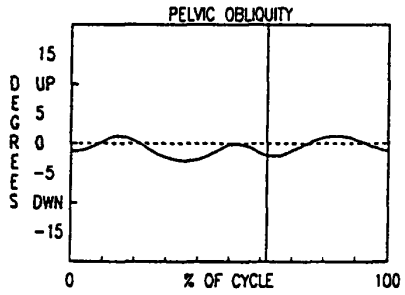
NAME:
DATE:
SIDE:
AGE:
DIAGNOSIS:
KEY:

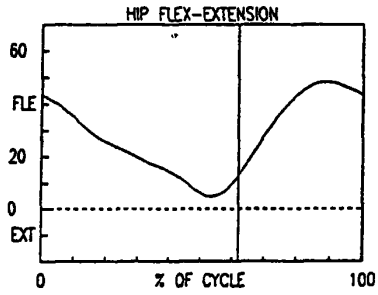
STUDY DATE	
SIDE	
OP TOE OFF (% CYC)	18%
OP FT STRIKE (% CYC)	50%
SNGL STANCE (% CYC)	32%
TOE OFF (% CYC)	68%
STEP LENGTH (CM)	25 cm
STRIDE LENGTH (CM)	50 cm
CYCLE TIME (SEC)	0.70 sec
CADENCE (STEPS/MIN)	171
VELOCITY (CM/SEC)	71
	n=40

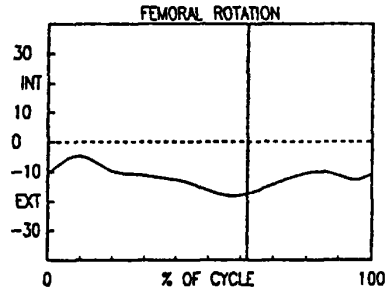
1.5 YEAR NORMAL ——

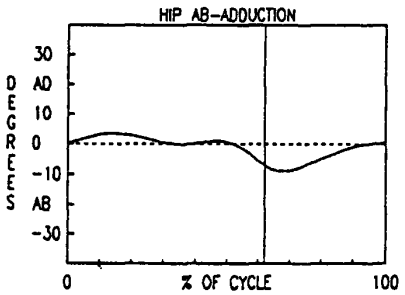


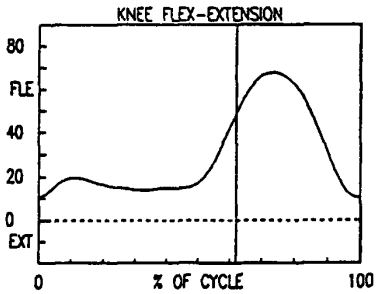


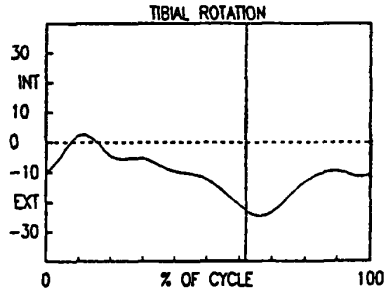


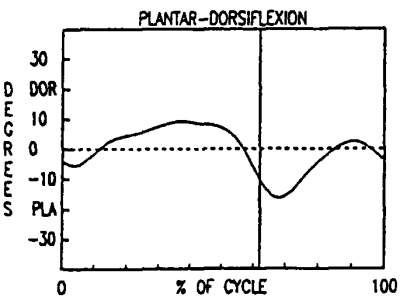


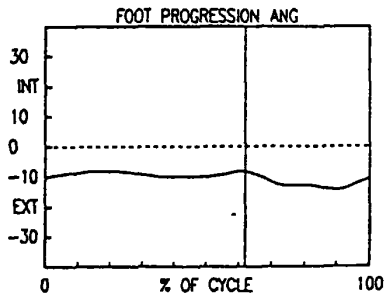












MOTION ANALYSIS LABORATORY
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NAME:
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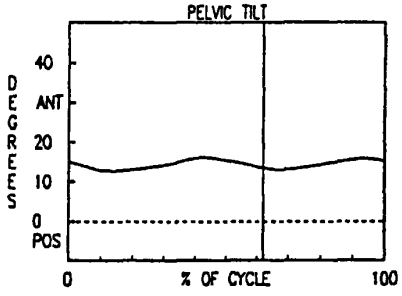
KEY:

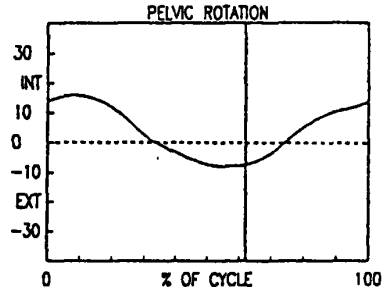
STUDY DATE

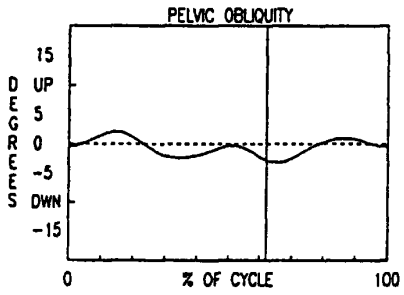
SIDE

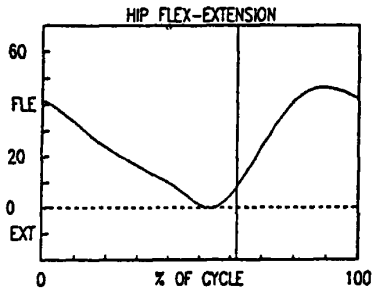
2.0 YEAR NORMAL

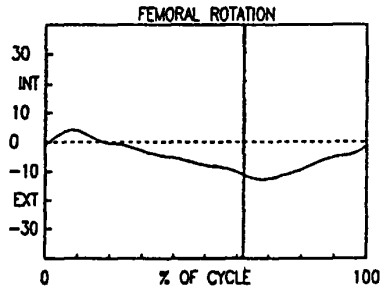
OP TOE OFF (% CYC)	17%
OP FT STRIKE (% CYC)	50%
SNGL STANCE (% CYC)	34%
TOE OFF (% CYC)	67%
STEP LENGTH (CM)	28 cm
STRIDE LENGTH (CM)	55 cm
CYCLE TIME (SEC)	0.78 sec
CADENCE (STEPS/MIN)	156
VELOCITY (CM/SEC)	72
	n=45

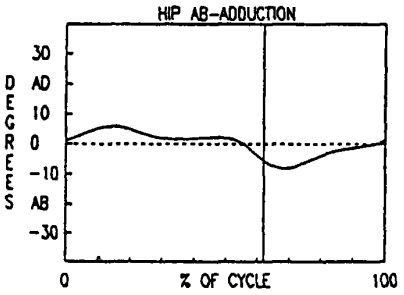


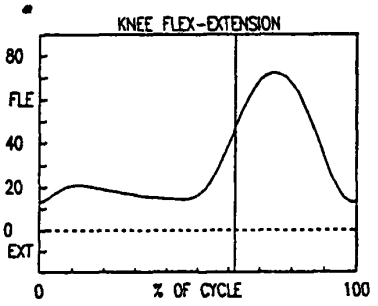


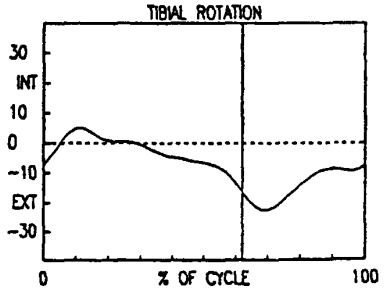


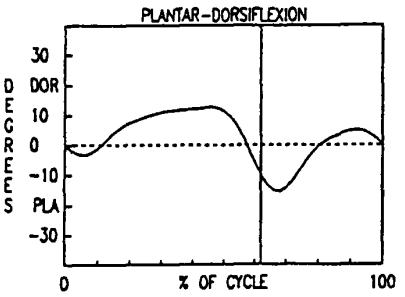


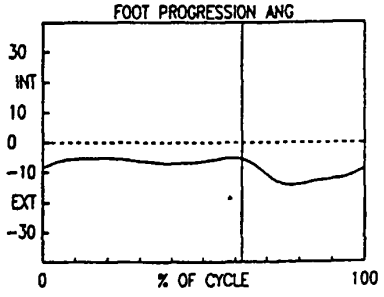












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NAME:
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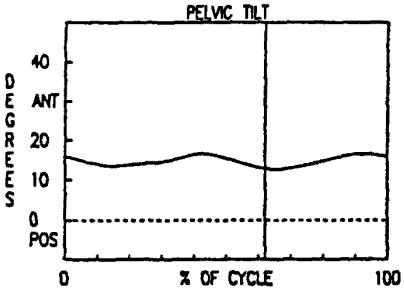
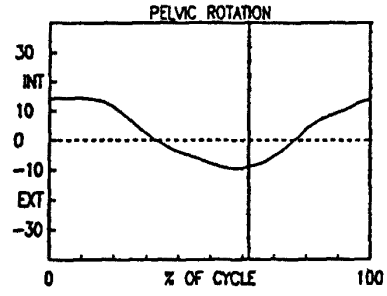
STUDY DATE

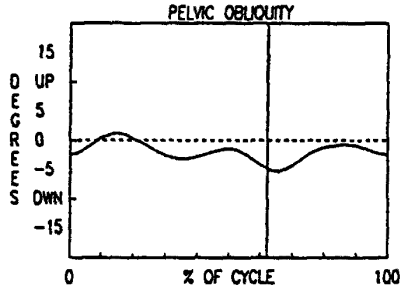
SIDE

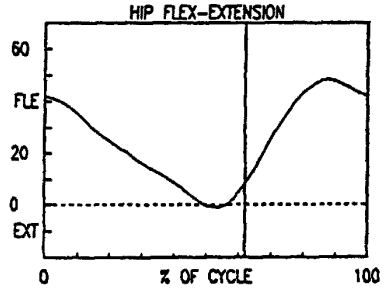
2.5 YEAR NORMAL

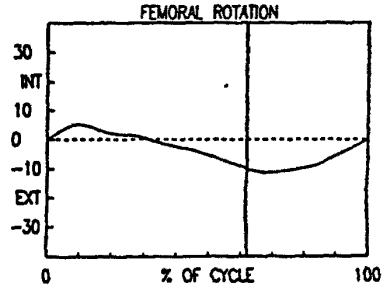
OP TOE OFF (% CYC)	16%
OP FT STRIKE (% CYC)	50%
SNGL STANCE (% CYC)	35%
TOE OFF (% CYC)	66%
STEP LENGTH (CM)	31 cm
STRIDE LENGTH (CM)	62 cm
CYCLE TIME (SEC)	0.77 sec
CADENCE (STEPS/MIN)	154
VELOCITY (CM/SEC)	81
	n=36

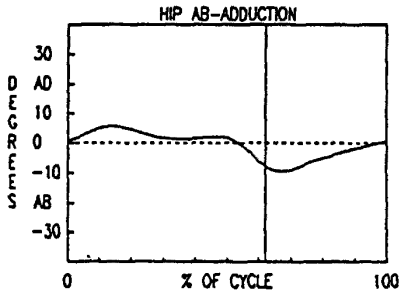


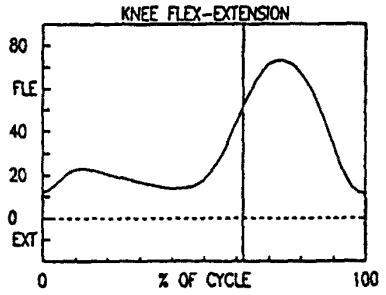


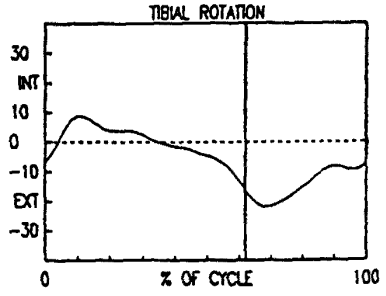


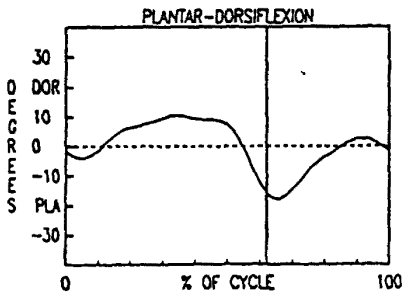


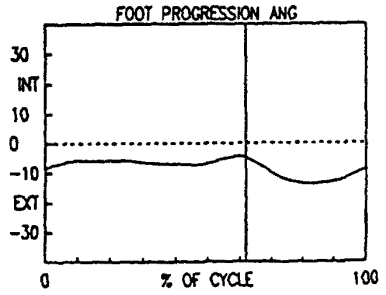












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NAME:
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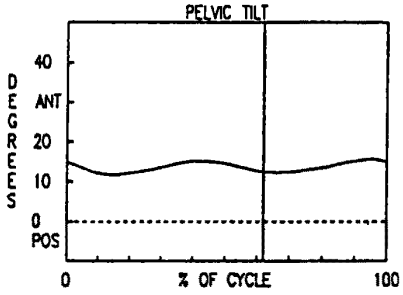
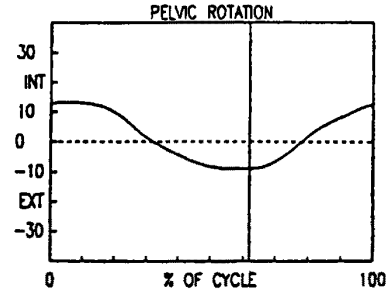
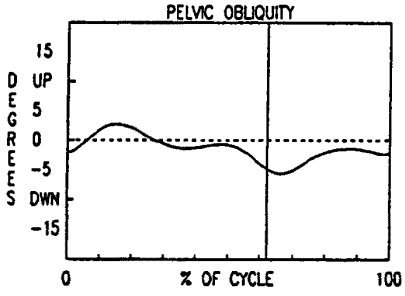
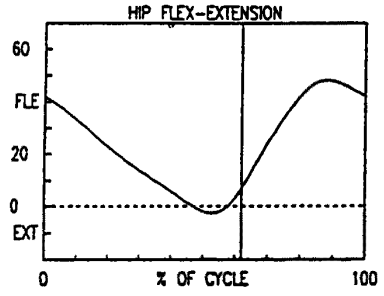
STUDY DATE	
SIDE	
OP TOE OFF (% CYC)	16%
OP FT STRIKE (% CYC)	50%
SNGL STANCE (% CYC)	35%
TOE OFF (% CYC)	66%
STEP LENGTH (CM)	33 cm
STRIDE LENGTH (CM)	67 cm
CYCLE TIME (SEC)	0.77 sec
CADENCE (STEPS/MIN)	154
VELOCITY (CM/SEC)	86
	n=47

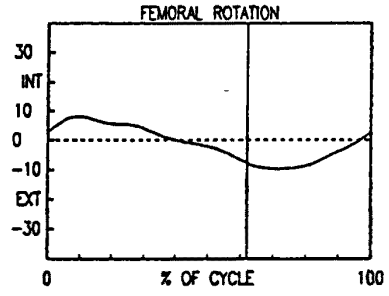
3.0 YEAR NORMAL ——

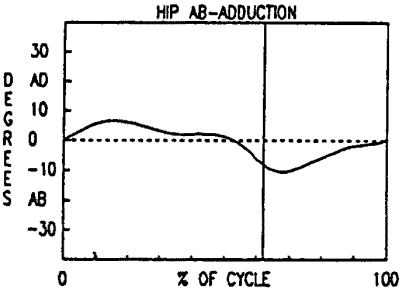


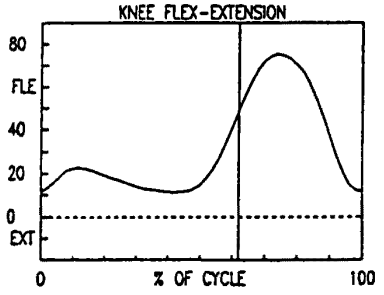


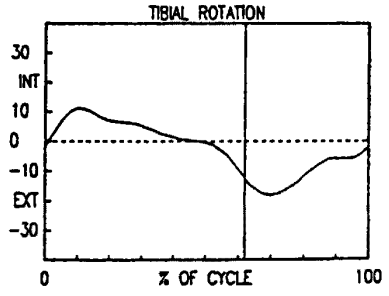


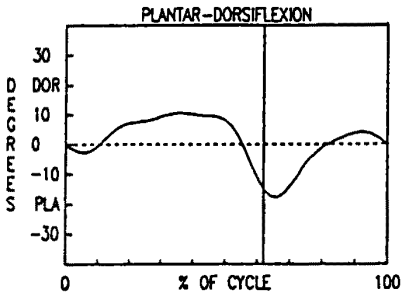


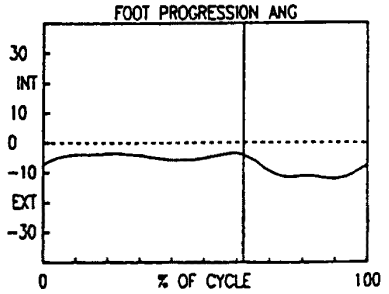












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NAME:
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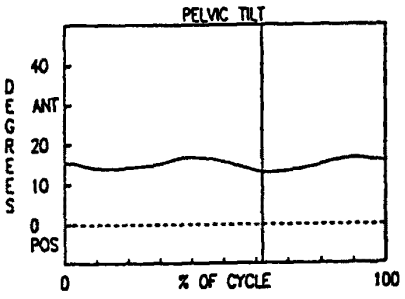
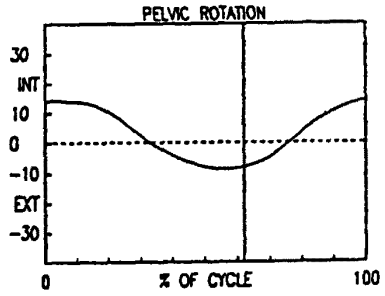
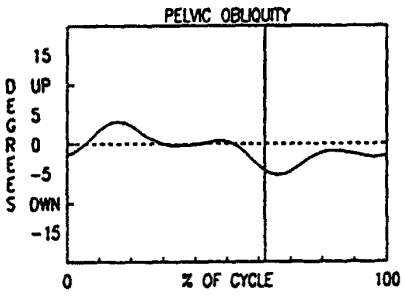
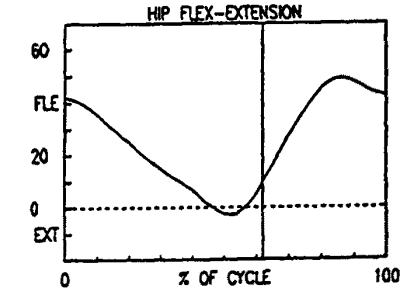
STUDY DATE	
SIDE	
OP TOE OFF (% CYC)	14%
OP FT STRIKE (% CYC)	50%
SNGL STANCE (% CYC)	36%
TOE OFF (% CYC)	65%
STEP LENGTH (CM)	37 cm
STRIDE LENGTH (CM)	74 cm
CYCLE TIME (SEC)	0.74 sec
CADENCE (STEPS/MIN)	160
VELOCITY (CM/SEC)	99
	n=40

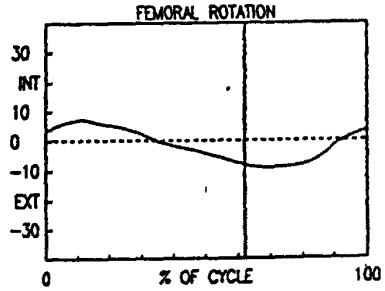
3.5 YEAR NORMAL ——

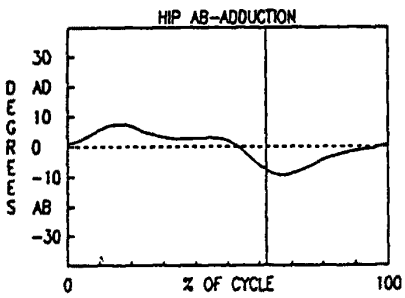


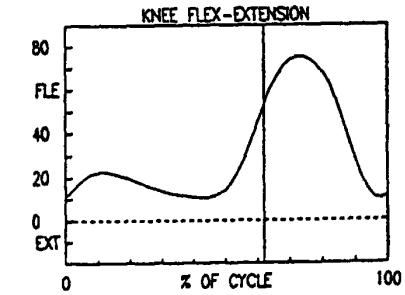


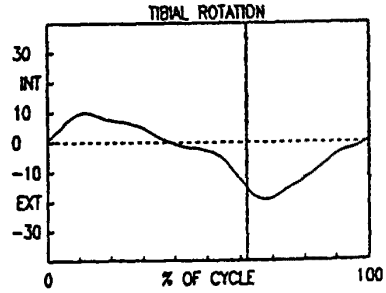


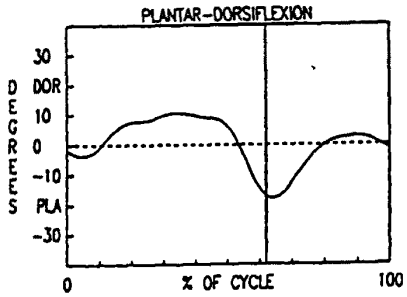


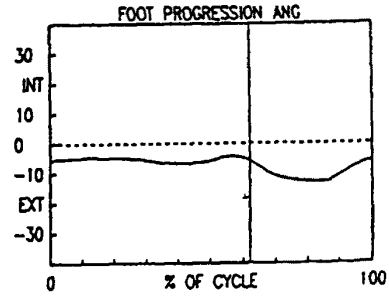










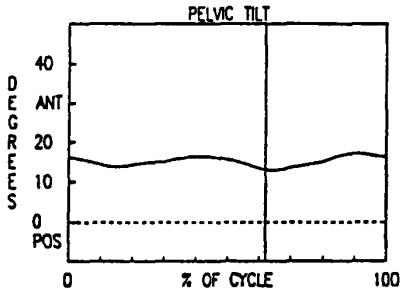


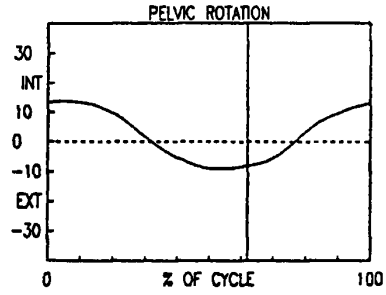
MOTION ANALYSIS LABORATORY
CHILDREN'S HOSPITAL & HEALTH CENTER
SAN DIEGO, CALIFORNIA 92123

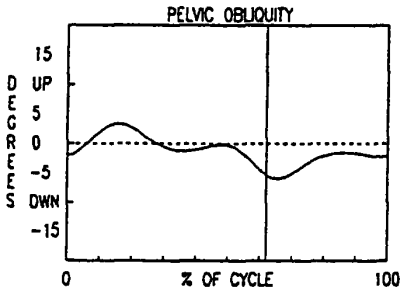
NAME:
DATE:
SIDE:
AGE:
DIAGNOSIS:
KEY:

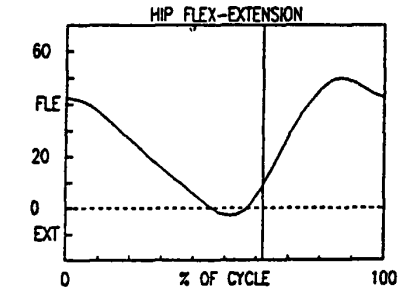
STUDY DATE	
SIDE	
OP TOE OFF (% CYC)	14%
OP FT STRIKE (% CYC)	50%
SNGL STANCE (% CYC)	36%
TOE OFF (% CYC)	64%
STEP LENGTH (CM)	39 cm
STRIDE LENGTH (CM)	78 cm
CYCLE TIME (SEC)	0.78 sec
CADENCE (STEPS/MIN)	152
VELOCITY (CM/SEC)	99
	n=39

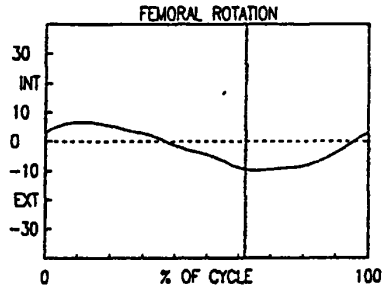
4.0 YEAR NORMAL ——

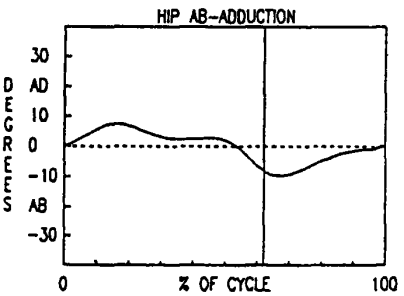


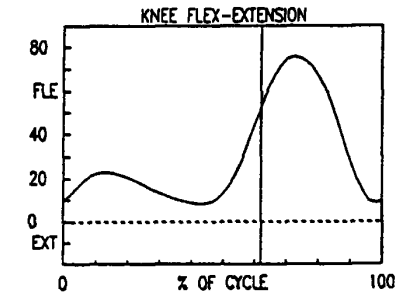


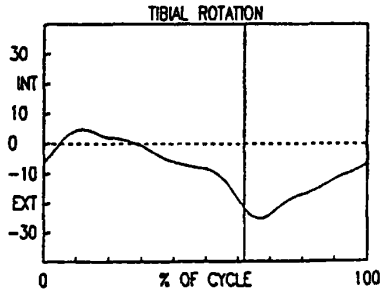


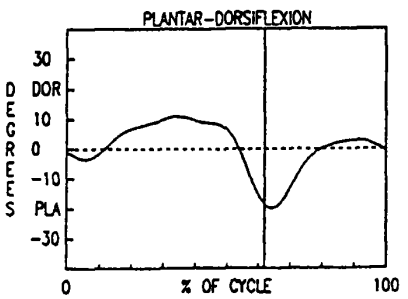


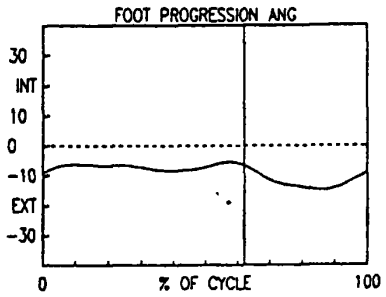












MOTION ANALYSIS LABORATORY
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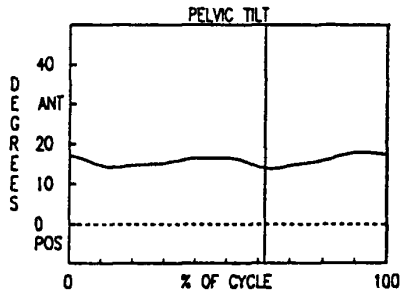
NAME:
DATE:
SIDE:
AGE:
DIAGNOSIS:
KEY:

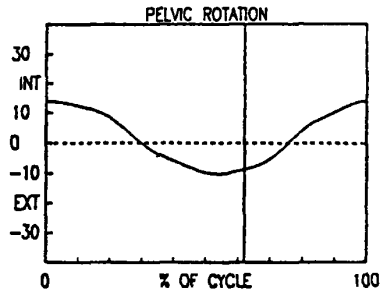
STUDY DATE

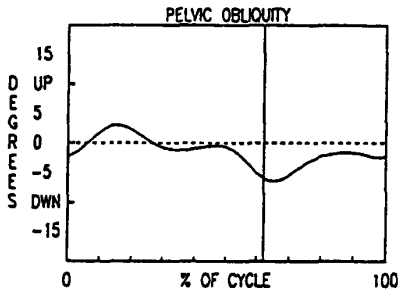
5.0 YEAR NORMAL

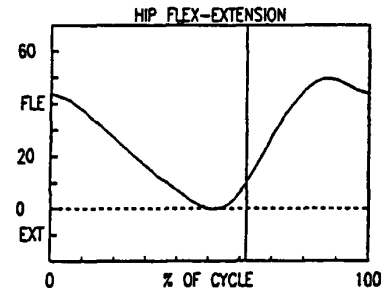
SIDE

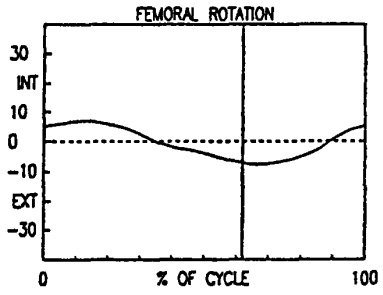
OP TOE OFF (% CYC)	13%
OP FT STRIKE (% CYC)	50%
SNGL STANCE (% CYC)	37%
TOE OFF (% CYC)	63%
STEP LENGTH (CM)	42 cm
STRIDE LENGTH (CM)	84 cm
CYCLE TIME (SEC)	0.77 sec
CADENCE (STEPS/MIN)	153
VELOCITY (CM/SEC)	108
	n=42

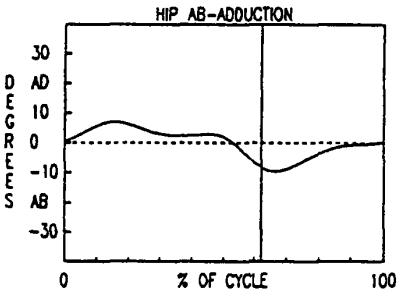


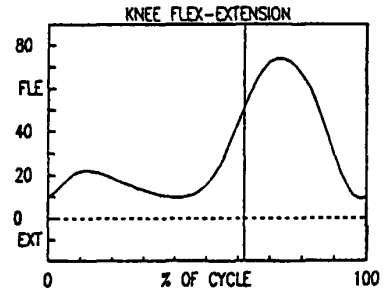


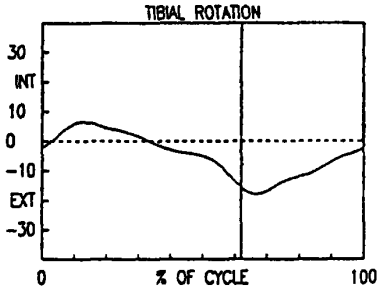


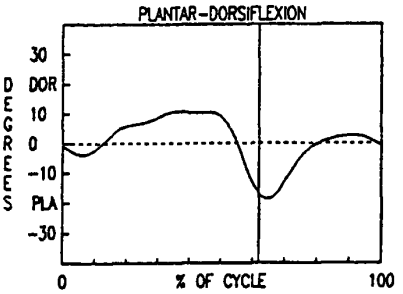


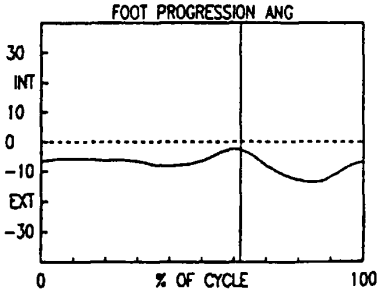












MOTION ANALYSIS LABORATORY
CHILDREN'S HOSPITAL & HEALTH CENTER
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NAME:
DATE:
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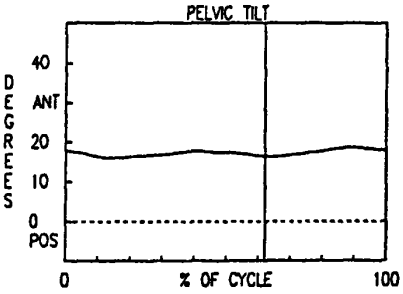
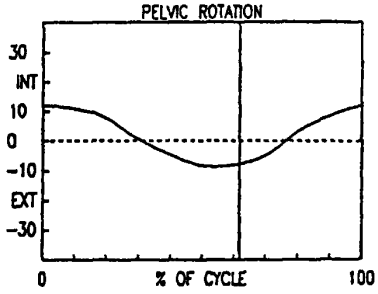
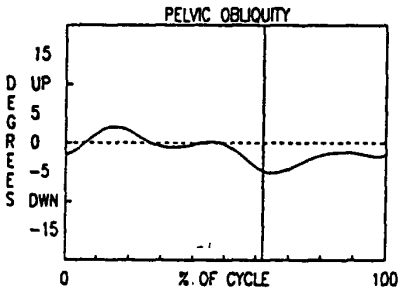
KEY:

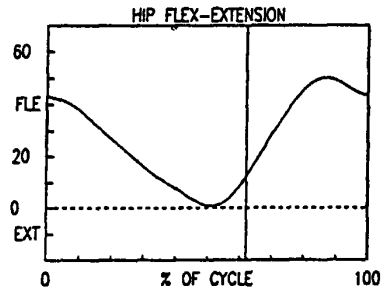
STUDY DATE	
SIDE	
OP TOE OFF (% CYC)	13%
OP FT STRIKE (% CYC)	50%
SNGL STANCE (% CYC)	37%
TOE OFF (% CYC)	64%
STEP LENGTH (CM)	44 cm
STRIDE LENGTH (CM)	89 cm
CYCLE TIME (SEC)	0.82 sec
CADENCE (STEPS/MIN)	146
VELOCITY (CM/SEC)	109
	n=44

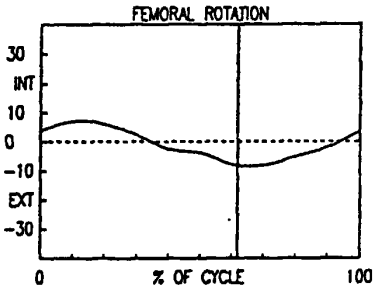
6.0 YEAR NORMAL ——

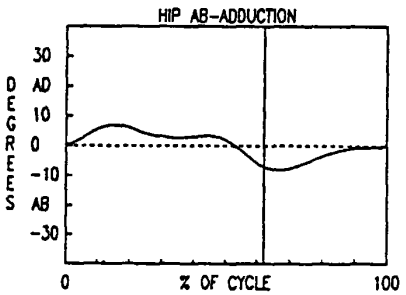


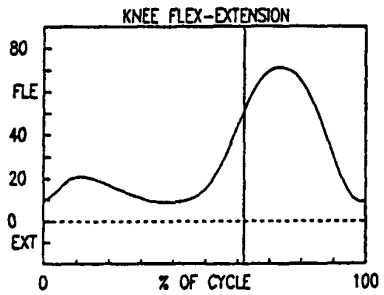


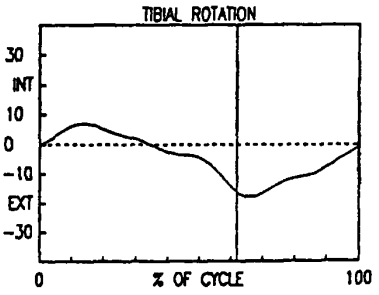


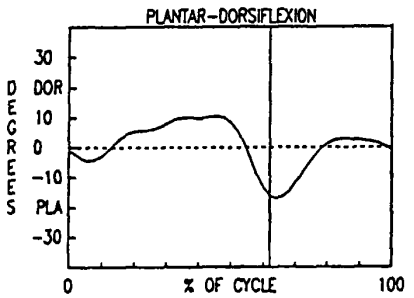


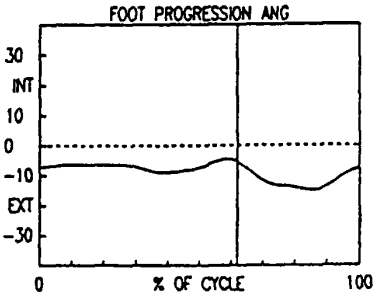












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NAME:
DATE:
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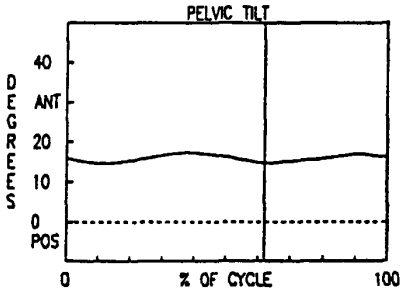
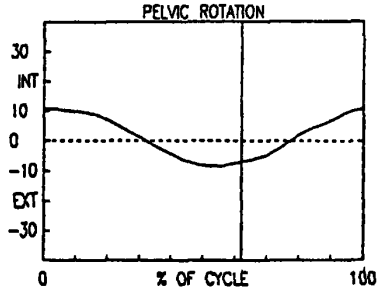
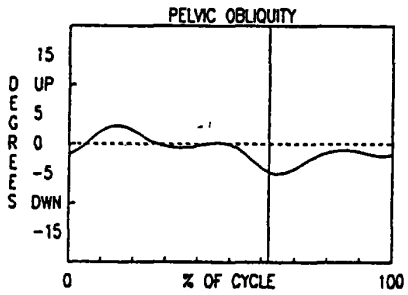
KEY:

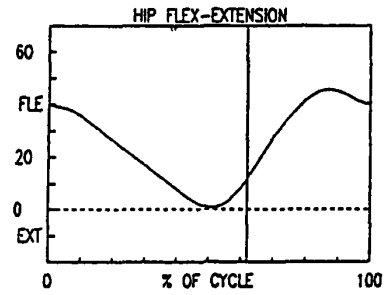
STUDY DATE	
SIDE	
OP TOE OFF (% CYC)	12%
OP FT STRIKE (% CYC)	50%
SNGL STANCE (% CYC)	38%
TOE OFF (% CYC)	62%
STEP LENGTH (CM)	48 cm
STRIDE LENGTH (CM)	97 cm
CYCLE TIME (SEC)	0.83 sec
CADENCE (STEPS/MIN)	144
VELOCITY (CM/SEC)	114
	n=46

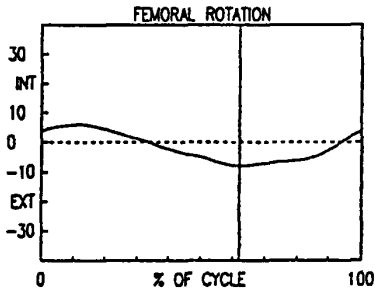
7.0 YEAR NORMAL ——

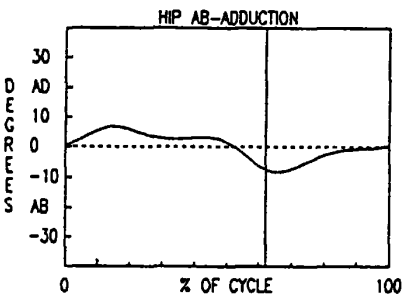


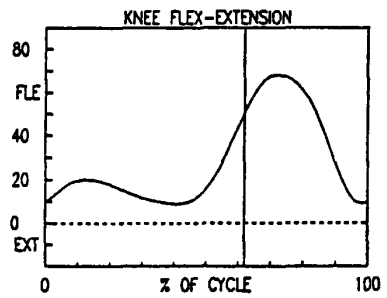


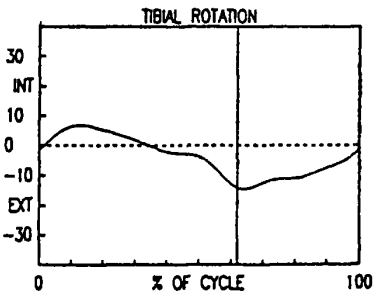


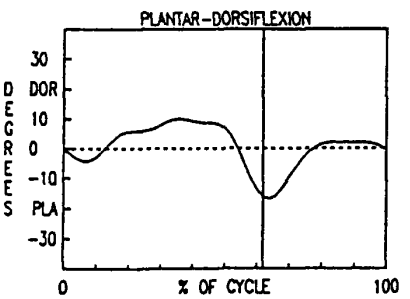


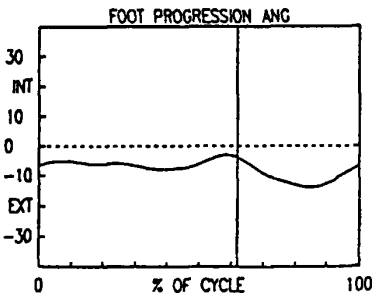












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NAME:
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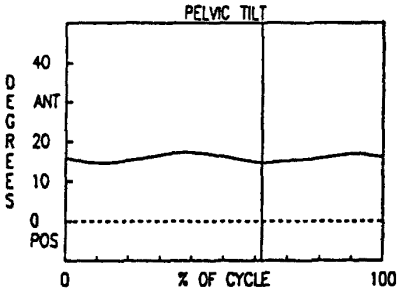
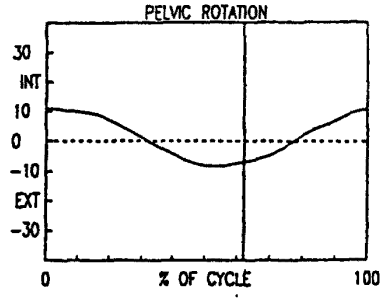
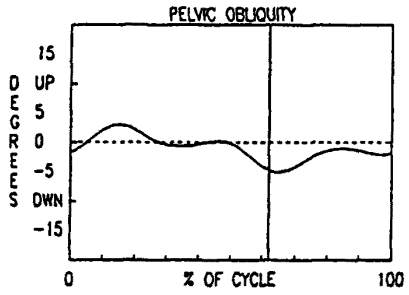
KEY:

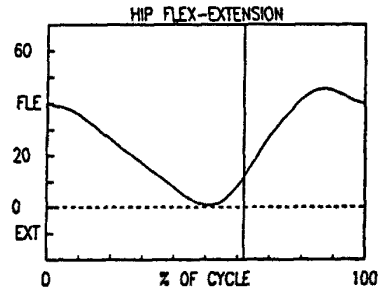
STUDY DATE	
SIDE	
OP TOE OFF (% CYC)	13%
OP FT STRIKE (% CYC)	50%
SNGL STANCE (% CYC)	37%
TOE OFF (% CYC)	64%
STEP LENGTH (CM)	66 cm
STRIDE LENGTH (CM)	129 cm
CYCLE TIME (SEC)	1.06 sec
CADENCE (STEPS/MIN)	114
VELOCITY (CM/SEC)	123
	n=22

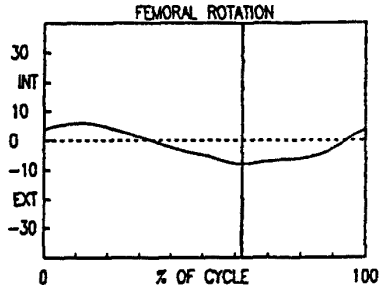
ADULT NORMAL ——

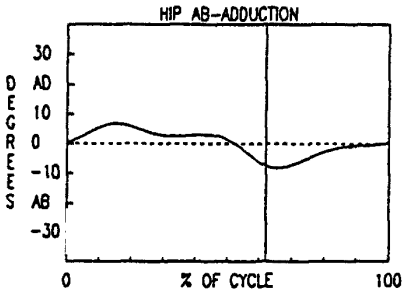


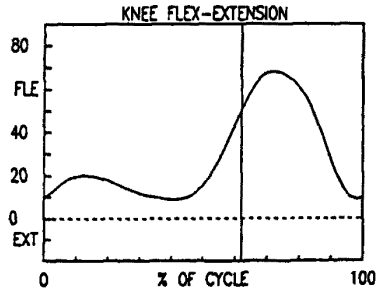


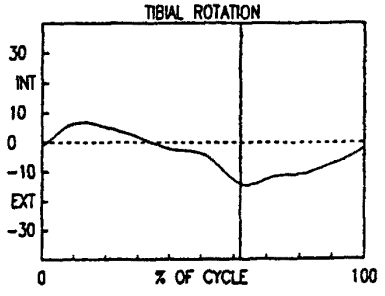


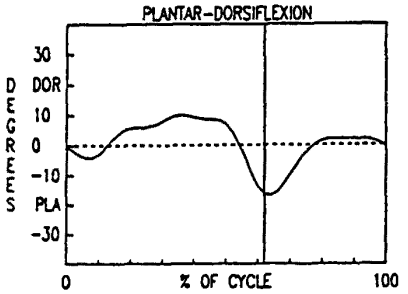


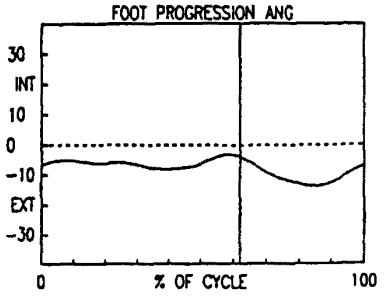












附錄(四)

Protocol for Fine-Wire Electromyography Collection

ELECTROMYOGRAPHY: FINE-WIRE TECHNIQUE

PROTOCOL FOR EMG COLLECTION-INTERNAL ELECTRODES

MOTION ANALYSIS LABORATORY
SAN DIEGO, CA

EQUIPMENT:

Sterile towel, needle pack (contains sterile electrodes and hemostat), alcohol wipes, peroxide, 2 x 2 gauze pads, ground strap, black amplifier box, electrode connectors, footswitches, scissors, tweezers, gloves, paper tape, plastic tape, and belt.

Turn on the power to the stimulator 30 minutes before needed, to allow an adequate time to warm up.

1. PREPARATION OF THE ELECTRODES:

Prepare a clean field with the sterile towel.
Open the needle pack and slide the inner pack onto the towel.
While holding the plastic hypodermic case, gently slide the needle out.
Move the clamp to the base of the bevel so the therapist can grasp the needle base for insertion. Check that the wires within the bevel of the needle slide independently of each other. Check that the tips of the wires have been bared (the insulation burned off) and are not touching each other.
Hand the electrode to the therapist or doctor, or replace the needle within the plastic cap until it is needed.

2. PLACING THE ELECTRODE:

It is mandatory to wear gloves. Select the insertion site. Clean the skin with an alcohol wipe. Using assistance, restrain the patient adequately to ensure proper insertion and needle withdrawal. Insert the electrode, withdraw the needle slowly, holding the wires at the skin so as not to pull them out with the needle. Clean away any blood with a peroxide-soaked gauze pad. Dispose of gauze pads in red plastic bag labeled Biohazardous Waste.

CAUTION: WEAR GLOVES WHEN HANDLING ANYTHING THAT HAS BEEN EXPOSED TO BLOOD.

3. CONNECTING THE ELECTRODES:

San Diego Lab uses a spring-type connector. Secure the connector to the skin by criss-crossing thin strips of Transpore tape across the connector. It is advisable to put a small loop in the distal connector wire to allow some play in the wire.
Attach the electrode wire to the connectors. Remove the insulation from the wire by twisting each spring several times.
Trim the excess wire at the spring connector with sharp scissors.

CONNECTING THE ELECTRODES (continued):

Attach the ground to a bony landmark or other electrically non-related area on the patient's lower extremity.
Plug the connectors into the black box.
Record the muscles studied with their corresponding numbered connector on the EMG data sheet.

4. VERIFY THE SIGNAL:

Using the audio-amplifier: Turn to the channel corresponding to the number of the connector you are testing. Tap each connection site (positive and negative). Encourage a muscle contraction while listening to the signal. If there is a noisy, abrupt sound inconsistent with any form of pattern, the wires may be shorting. You will need to adjust the wire by pulling one of them out slightly. If there is audible 60 Hz interference (humming noise), attempt to eliminate the problem by one of the following: check all connections, check ground, check open and closed channels on amplifier box, check for excess fine-wire protruding from spring connectors, change connector.

5. STIMULATION:

- Use the GRASS stimulator in the console. Power up the stimulator (it normally comes on when the entire console is powered up). A 30 minute warm up time is advisable before using. The stimulator has two separate cables arising from the front of the console. The technician will attach the first cable with the EZ clips onto the loops of the spring connector. This cable supplies the electrical impulse needed for stimulation. The therapist or physician will stimulate the electrode by pushing the red button on the end of the second heavy black cable arising from the front of the GRASS stimulator. A red light will be seen on the front right lower corner of the stimulator, confirming stimulation. When this red light is seen, the technician will increase the stimulation by one-half of a unit with 15 units on the dial, or until the therapist or physician says to halt. Stimulate until the therapist confirms the electrode placement. Write "CBS" (confirmed by stimulation) on the EMG data sheet.

6. DATA COLLECTION:

See Data Collection for Surface EMG Collection

7. REMOVAL OF WIRES:

REMEMBER TO WEAR GLOVES

The therapist or physician will remove the wires by pulling both straight out. A quick check of the wires is recommended to see that nothing remains embedded in the muscle (the barbs are easily spotted). Place a bandage if needed. The wires, and any gauze, gloves or tissue with blood on it, should be handled using the infectious material handling procedures. While wearing gloves, place all contaminated material into a small red plastic bag labeled for infectious material. Place this bag for disposal by Environmental Services.

KEMG REFERENCES

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Related articles from this list of journals:
Clinical Orthopedics and Related Research
Gait and Posture
Journal of Bone and Joint Surgery
Physical Therapy

ELECTROMYOGRAPHY
FINE-WIRE TECHNIQUE

REQUIREMENTS FOR KINESIOLOGICAL ELECTROMYOGRAPHY CERTIFICATION IN CALIFORNIA

I. DEFINITION:

Kinesiological electromyography means the study, including tissue penetration, of the phasic activity of individual or multiple muscles in relation to another physical or physiological event or exercise and does not include the evaluation of specific abnormal potentials or evoked responses.

"No physical therapist shall perform tissue penetration for the purpose of making an electromyographical evaluation unless he or she is certified by the committee...or such practice is appropriately supervised in order to meet the experience requirements for examination by the committee for certification." *State of California Physical Therapist Examining Committee, 9/2/94.*

II. REQUIREMENTS FOR CERTIFICATION:

A. Licensure: Be licensed as a physical therapist by the board.

B. Training: Provide evidence of 10 clock hours of training in tissue penetration under the supervision of a licensed physician or physical therapist certified in KEMG that includes instruction and demonstration in:

1. Pertinent anatomy and physiology
2. Choice of equipment
3. Proper technique
4. Hazards and complications
5. Post-test care
6. Satisfactory performance in the technical skills of tissue penetration.

C. Education: Provide evidence of <u>one</u> of the following:

1. Completion of course work from accredited university or state college. Course work to include:

   a. Gross anatomy
   b. Neuroanatomy
   c. Nerve and muscle physiology

2. Completion of a period of self-study including documentation of materials studied and clinical exposure to EMG.

3. Authorization to perform EMG issued by another state with similar requirements.

D. Experience: Provide evidence of the following:

1. Completion of not less than 200 clock hours in kinesiological electromyography under the supervision of a certified KEMG Physical Therapist or a licensed physician who performs EMG in his or her practice.

2. Documentation of completion of 50 kinesiological electromyography examinations.

III. EXAMINATION SUBJECT AREAS:

A. Basic science as related to kinesiological EMG.

1. Anatomy
2. Electrophysiology

B. Clinical science as related to kinesiological EMG.

1. Pre-examination patient evaluation
2. Instrumentation
3. Kinesiological examination procedure and process

C. Practical application of kinesiological EMG.

1. Needle/wire examination of muscles
2. Handling of equipment
3. Patient preparation and management
4. Data collection, presentation and summarization

IV. RECORD KEEPING (SUGGESTION)

See attached

V. CURRENT FEE STRUCTURE:

A. Application fee - $100.00
B. Written examination fee - $500.00
C. Biennial renewal fee - $50.00

MUSCLE INSERTIONS

#	Date	Patient's Name	Muscle	C	√
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
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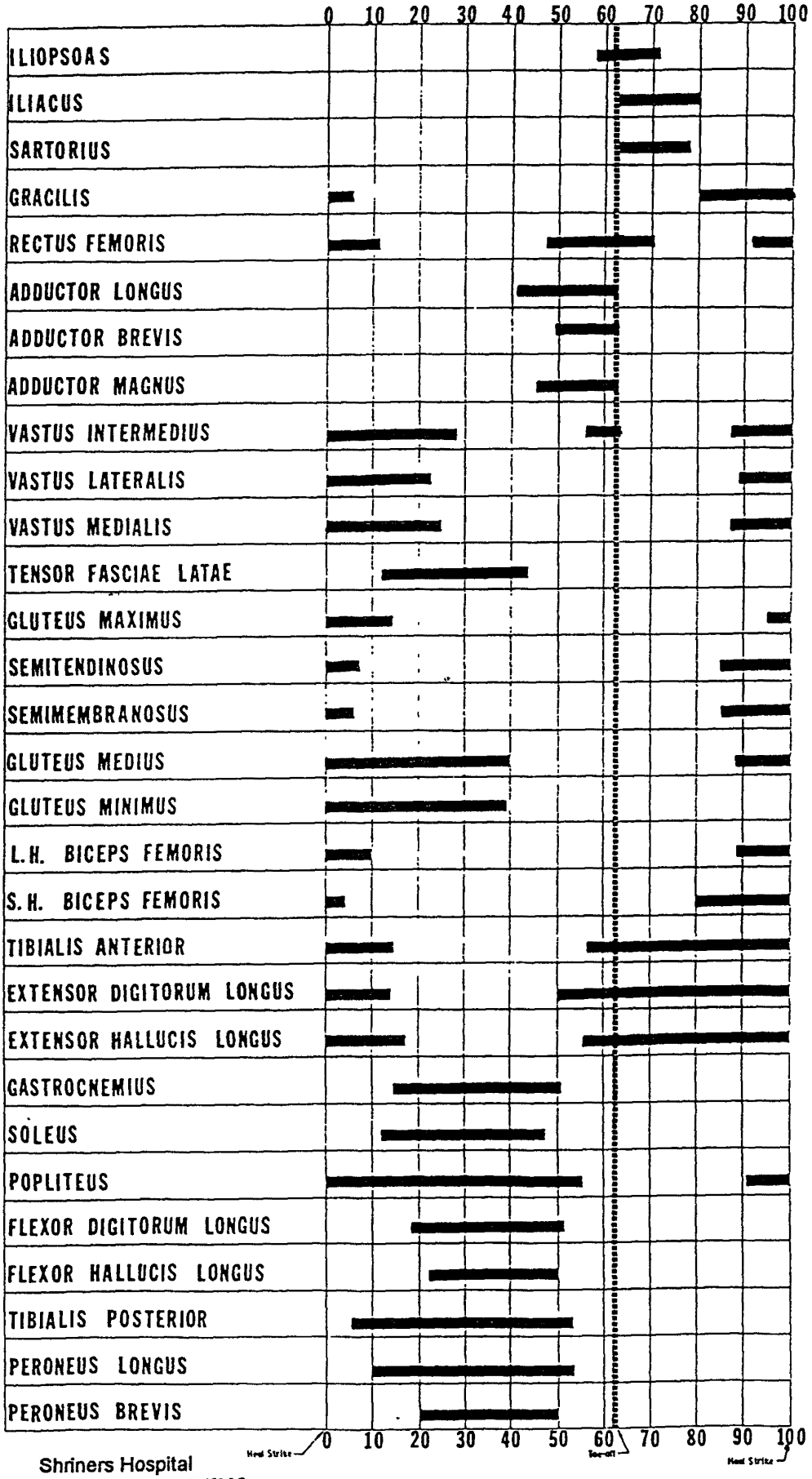
23					
24					
25					

NORMAL ELECTROMYOGRAPHIC DATA

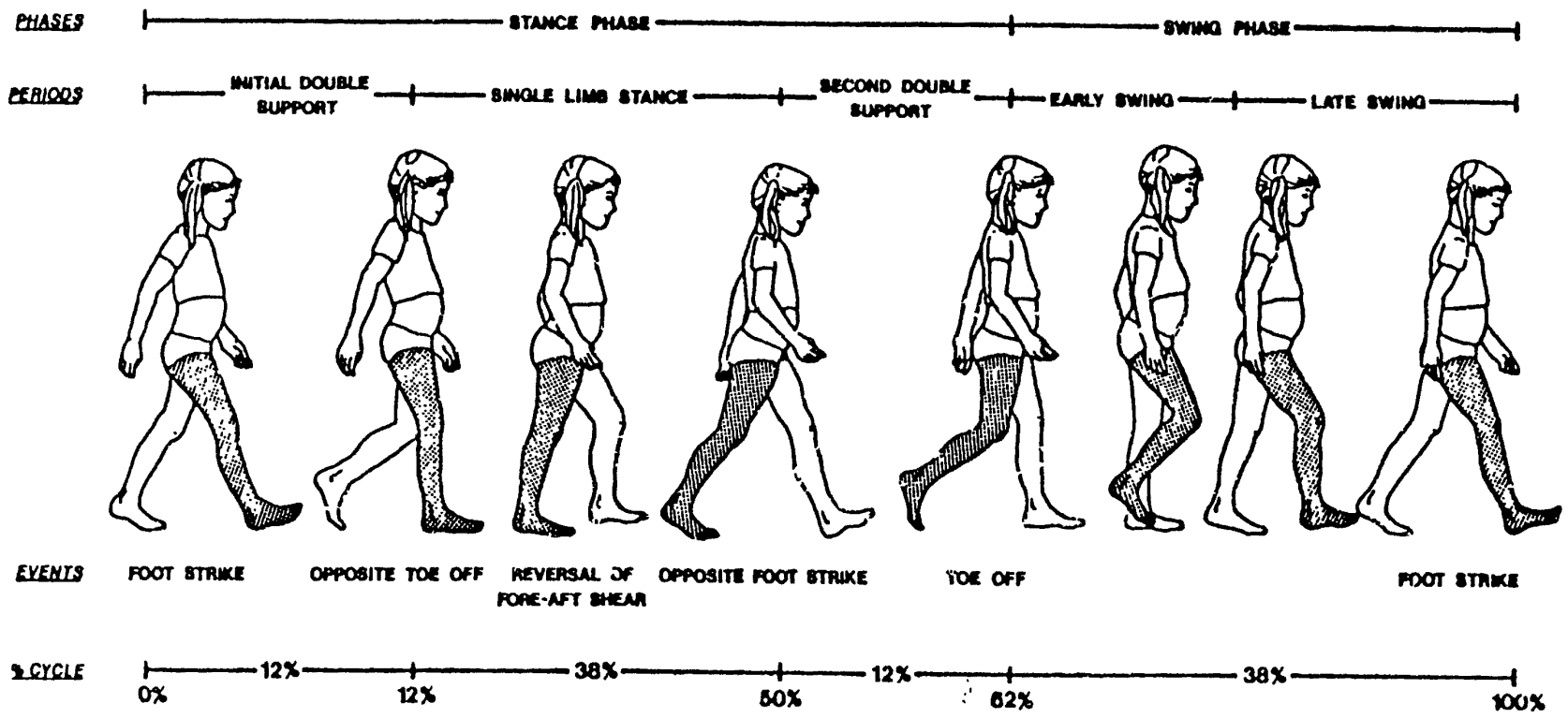


Shriners Hospital
San Francisco-Adult EMG

Children's Hospital and Health Center

CHILDREN'S HOSPITAL & HEALTH CENTER
MOTION ANALYSIS LABORATORY
SAN DIEGO, CALIFORNIA

TYPICAL NORMAL WALK CYCLE



MOTION ANALYSIS LABORATORY
CHILDREN'S HOSPITAL & HEALTH CENTER
SAN DIEGO, CALIFORNIA 92123

NAME
DATE
SIDE
AGE
DIAGNOSIS
KEY:

STUDY DATE

SIDE

OP TOE OFF (% CYC)

OP FT STRIKE (% CYC)

SNGL STANCE (% CYC)

TOE OFF (% CYC)

STEP LENGTH (CM)

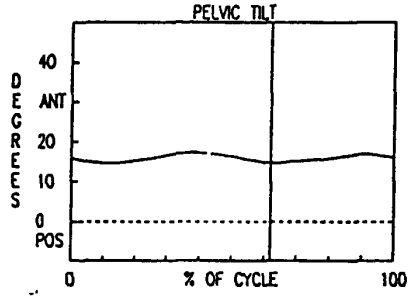
STRIDE LENGTH (CM)

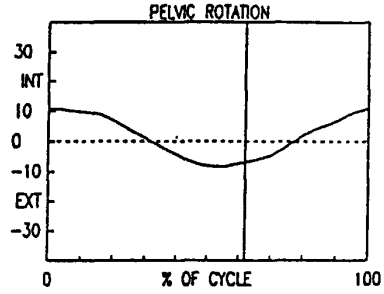
CYCLE TIME (SEC)

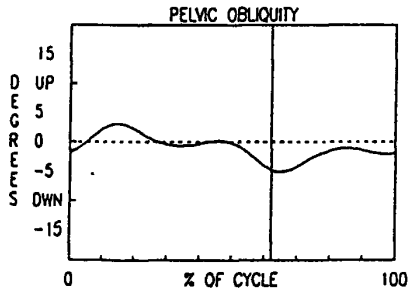
CADENCE (STEPS/MIN)

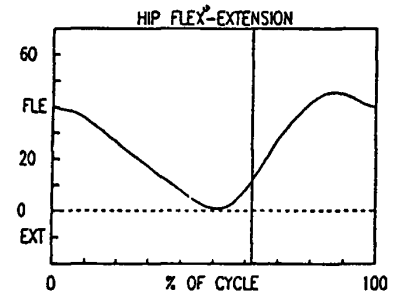
VELOCITY (CM/SEC)

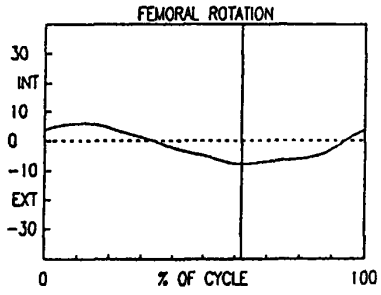
ADULT NORMAL

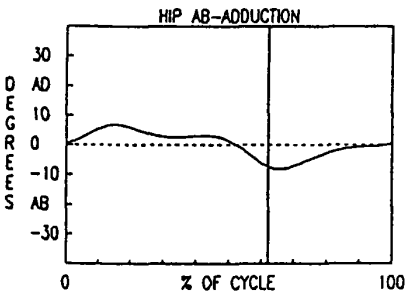


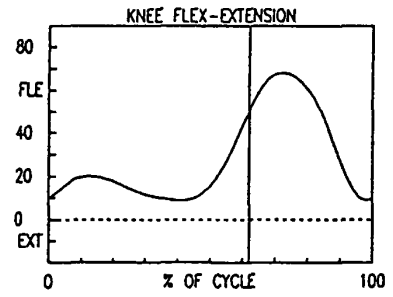


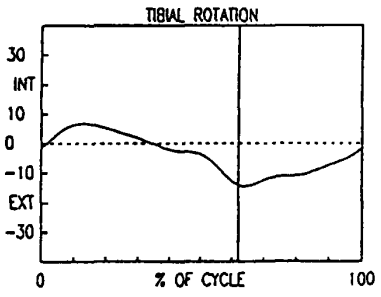


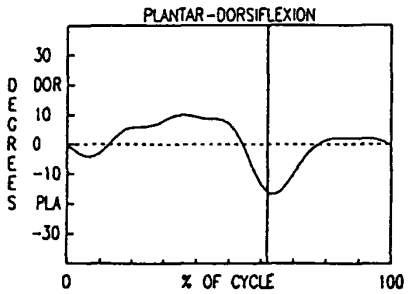


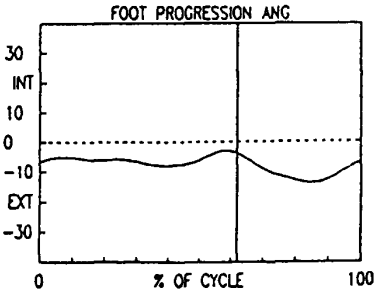












ıildren's

Children's Hospital - San Diego
3020 Children's Way / MC 5054
San Diego, California 92123-4282
Motion Analysis Laboratory
(858) 576-5807 / FAX: (858)514-7494

Motion Analysis Lab - 5054
Children's Hospital
3020 Children's Way
San Diego, CA 92123-4282

Physician's Order Request

Complete & Return
to: MAL - MC5054

PATIENT INFORMATION

NT NAME	DOB
ESS	PHONE NUMBER
RRING PHYSICIAN	PHONE NUMBER

Diagnosis: _____

Previous Surgeries: ☐ No ☐ Yes (If Yes, Please List): _____

_____

Assistive Devices? Braces: ☐ No ☐ Yes
Walker: ☐ No ☐ Yes
Crutches: ☐ No ☐ Yes

Clinical Problem: _____

atment Being Considered: _____

FUNDING

☐ CCS ☐ MEDI-CAL ☐ INSURANCE:
What Kind? ☐ COMMERCIAL ☐ HMO ☐ PPO

Study Authorized? ☐ Yes ☐ No Authorization Number: _____ ☐ Not Necessary

ORDERS

☐ Gait Study **(Includes Motion, Force, EMG, Video)**

☐ Video Documentation **(Independent Procedure)**

☐ Hand Study

☐ TEKscan Foot Pressure: ☐ Right ☐ Left ☐ Bilateral
☐ Barefoot ☐ In-Shoe ☐ In-Orthotics

Special Requests (List): _____

_____

_____

_____

_____

_____

_____

_____

tment Facility (Where Seen):

CIAN'S SIGNATURE	DATE

附錄(五)

The Sensors Glossary of Data Acquisition and Signal Processing

The *Sensors* Glossary of Data Acquisition and Signal Processing

Ed Ramsden, Cherry Electrical Products

This glossary was so popular last year that we're running it again, with a few additions. And you might want to visit www.sensorsmag.com/da98 for another helping of *Sensors Data Acquisition* Alphabet Soup, which spells out 105 terms you usually encounter as initials only.

Accuracy. The maximum error of a measured value with respect to its true theoretical value.

Acquisition Time. The time required for the front end of a DA board to capture an input signal and hold it to within a specified error band after a sample command is received.

Active Filter. An electronic filter that incorporates gain-providing elements such as op amps or transistors. Active filter techniques allow filters to be implemented without inductors.

ActiveX Control. A form of reusable software component available under Microsoft's Windows operating system. Often used to implement drivers for DA hardware.

Algorithm. A well-defined procedure that transforms one or more given input variables into one or more output variables in a finite number of steps.

Alias. A false low-frequency signal that appears when reconstructing analog data that were sampled at an insufficient rate. See Nyquist limit.

Analog Multiplexer. A set of mechanical or electronic switches that connect one of several analog inputs to a common analog output, so as to allow a single ADC to sample data from several inputs.

Analog Signal Processing. Techniques for processing signals while they are still represented as continuous values, typically voltages. Some common analog signal processing operations are filtering, limiting, linearization, and temperature compensation.

Analog-to-Digital (A/D) Conversion. The process of converting a continuous analog signal to a digital value that represents that signal at the instant at which it was sampled.

Analog-to-Digital Converter (ADC). A device that converts an analog signal to a digital value.

Analog Trigger. A trigger that occurs at a user-selectable point of an incoming analog signal. Triggering can be set to occur at a specific level on either an increasing or a decreasing signal. This function is universally found in oscilloscopes and is often found in high-speed DA boards.

Anti-Aliasing Filter. An analog filter placed before an ADC for the purpose of removing high-frequency signal components that would cause aliasing.

Aperture Jitter. The variation in time required for a given S/H circuit to enter the hold mode. This variation causes uncertainty as to exactly when an incoming signal is actually sampled.

Aperture Time. The elapsed time between when a hold command is issued and when a S/H circuit holds the incoming signal.

Asynchronous Communications. Communications protocols in which data are transmitted at arbitrary points in time; most commonly used to refer to serial data transmission protocols such as RS-232 or RS-485.

Band-Pass Filter. A filter that allows only signals occurring between a lower and an upper frequency (the passband) to be passed through, and blocks all other signals.

Band-Stop Filter. A filter that blocks all signals occurring between a lower and an upper frequency (the stopband); also called a notch filter.

Bandwidth. The frequency range over which a system will pass or process incoming signals without significantly attenuating them. The range is often demarcated by the limits at which the system attenuates signals to $1/\sqrt{2}$ (0.707) of their original value, commonly called the -3 dB points.

Bipolar. An input or output in a DA system that accepts or provides signals of both positive and negative magnitudes.

Buffer. A memory device used to temporarily store data, typically to compensate for differences in speed between two system components (e.g., a DA board and main memory).

Burst Mode. See **Direct Memory Access.**

Call. A software instruction that passes control of a program to a subroutine. On completion of the subroutine, control returns to the original program at the instruction following the call instruction.

CODEC (COder/DECoder). A specialized data conversion circuit used for A/D and D/A conversion of audio signals. CODECs often contain compression and expansion circuitry so as to require fewer bits to represent a given analog signal.

Common Mode Input Range. The maximum range over which a differential input can accept a common mode signal and still be able to successfully extract the differential component.

Common Mode Rejection Ratio (CMRR). The ratio of a device's differential voltage margin (A_{dm}) to its common mode gain (A_{cm}). Expressed in decibels, CMRR is a measure of a device's ability to reject interference appearing as common mode signal. CMRR = 20 log (A_{dm}/A_{cm}).

Common Mode Signal (V_{cm}). The mathematical average, relative to the DA differential system's ground, of the signals present at a differential input. $V_{cm} = (V_{in1} - V_{in2})/2$, where V_{in1} and V_{in2} are the common mode signals present at each terminal of differential input.

Compensation. The technique of modifying data from a source to correct for the influence of additional environmental effects.

Control Register. A storage location on a DA board into which information is written to control its operation, e.g., channel, gain, conversion rate.

Conversion Rate. The speed of a DA system expressed in the number of conversions or samples per second.

Conversion Time. The time required by a DA system to make data available after a conversion command has been received.

Counter/Timer. A counter that either can operate as an event counter or can measure the time between two events.

Crosstalk. A phenomenon in which a signal on one line can interfere with signals on other lines; occurs with both analog and digital signals.

Current Loop. A method of transmitting an analog signal, in which the value of the signal is represented by the current drain of the transmitter. 4–20 mA is a popular standard, in which 4 mA represents the lowest end of the signal range and 20 mA represents the highest end. Current loop transmission is used because it is highly immune to noise.

Data Acquisition (DA). The process of converting information from real-world sources to a symbolic (usually digital) form in which it may be stored, manipulated, analyzed, and displayed.

Data Acquisition Board. A DA incorporated on a PCB that is electrically and mechanically compatible with a particular computer system.

Data Acquisition System (DAS). A system that processes one or more analog signals and converts them into digital form for use by a computer system.

Data File. Related pieces of data organized in a specific manner. Data files contain information but not instructions or programs. DASs often produce a series of time-sequenced measurands stored in a data file.

Data Logger. A DA system that incorporates a small computer, is typically portable, and is intended to collect data autonomously for extended periods of time. The data are afterward downloaded into another computer for processing and analysis.

Data Register. A register on a DA board from which data are read (such as those acquired by an ADC), or to which data are written (such as those to be output by a DAC).

Delta–Sigma (Δ–Σ) or Sigma–Delta (Σ–Δ) ADC. A high-accuracy ADC that samples at a higher rate and lower resolution than needed, and by means of various filtering techniques performs a rate for resolution tradeoff; commonly used for audio signal processing.

Differential Amplifier. An amplifier in which the output value is proportional to the difference between two input values [$V_o = K (V_{in1} - V_{in2})$], where K = gain; used to measure the difference voltage across a differential input.

Differential Input. An analog input configuration consisting of two terminals, isolated from system ground, across which a voltage difference is measured. Differential inputs are useful for interfacing with bridge-type sensors.

Differential Nonlinearity. The maximum deviation of any quantum (LSB change) from the ideal theoretical size of FSR/2N in the transfer function of a DA system.

Digital Filter. An algorithm that performs filtering on a signal after it has been sampled and converted to the digital domain by an ADC.

Digital-to-Analog (D/A) Conversion. The process of converting a digital value or code into an analog signal.

Digital-to-Analog Converter (DAC). A device that converts a digital value or code into an analog signal

Digital Signal Processing (DSP). Techniques for modifying and analyzing a signal after it has been sampled and converted into the digital domain by an ADC. DSP is becoming increasingly popular be cause of the flexibility in signal processir that it provides and the rapidly decreasing prices of microprocessors that are fast enough to implement the DSP algorithms in real time.

Digital Signal Processor (DSP). A microprocessor optimized to implement DSP algorithms such as digital filters. DSPs often contain onchip memory and can provide order-of-magnitude higher performance than general-purpose microprocessors of comparable price.

Direct Memory Access (DMA). A method of transferring data directly from a peripheral such as a DAS to the main memory of a computer without having to route it through the CPU. This is the fastest method of transferring DA measurements.

Discrete Fourier Transform. A version of the Fourier transform that operates on data that have been sampled at discrete, uniformly spaced points in time.

Double-Buffered DAC. A D/A conversion in which data are first written to a temporary holding register before being transferred to the converter's DAC output register. This allows all output data to be written to a DA card, and then have all the DAC outputs simultaneously update on a single data transfer command.

Drift. The change in a reading or parameter over a set period of time due to variations in temperature or other environmental conditions.

Driver. The part of a software program that controls a specific hardware device such as a DA board or a printer. Drivers simplify software development by hiding unnecessary levels of detail from the user, by providing a standardized user interface, and by ensuring that the hardware device operates in peaceful coexistence with the rest of the computer system.

Droop. The change in output voltage of a S/H circuit during a hold cycle.

Dynamic Range. The ratio of the largest signal a system can handle to the smallest signal it can reliably resolve. Dynamic range is typically expressed in decibels for analog systems and bits (N) for digital systems, where dB = 6.02 N = 20 log (larges signal/smallest signal resolved).

Effective Number of Bits (ENOB). The number of bits of resolution that an ADC can provide when various sources of noise, error, and distortion are taken into account. The ENOB for an ADC is always less than or equal to the advertised number of bits.

Event Counter. A device that counts the number of events (pulses) that are input to it.

Events per Unit Time (EPUT) Counter. A counter that totalizes the number of events in a given period; also called a frequency counter.

Excitation Circuit. A circuit on a DAS or signal conditioner that provides excitation voltage or current to power a sensor.

External Trigger. A voltage pulse from an external source that triggers an event such as an A/D conversion.

Fast Fourier Transform (FFT). An optimized version of the discrete Fourier transform that requires orders-of-magnitude less processing speed to implement.

Fibre Channel. ANSI standard under development for a high-speed computer channel that incorporates IPI, SCSI, and HiPPI command sets. Speeds range from 12.5 to 100 MBps using coax and optical fiber.

Filter. A device or algorithm that blocks certain signals while letting others pass.

Finite Impulse Response (FIR) Filter. A popular digital filtering algorithm that permits the implementation of a wide variety of filters and is unconditionally stable.

First-In/First-Out (FIFO) Buffer. A buffer in which the first data item stored is also the first retrieved; commonly used to temporarily store measurements on high-speed DA boards.

Flash A/D Converter. An ultrafast A/D conversion technique in which an array of 2N–1 comparators (for N bits) is used to perform the quantization; typically used in video-speed applications.

4-Wire Resistance Measurement. A way to measure the values of a resistor while avoiding errors caused by the wire runs. Two wires carry a current to the resistor, and two wires measure the voltage generated. It is commonly used with resistance temperature detectors (RTDs).

Fourier Transform. A mathematical technique that transforms a continuous function from its time-domain representation to its frequency-domain representation. The discrete Fourier transform performs the analogous function on discretely sampled data.

Frequency-to-Voltage (F/V) Converter. A device that converts a frequency input to a voltage input.

Full Scale (F.S.). The maximum specified range of a DAS.

Full-Scale Range (FSR). The difference between the minimum and maximum allowable input or output values for a DAS.

Full-Power Bandwidth. The bandwidth at which a system can accurately process a signal that extends over its F.S. range.

Function. See **Subroutine.**

Gain. The ratio of output to input for a given system; the slope of the transfer function at a particular point. For a linear system, gain is constant over the allowable range of the input.

Gain Drift. Change in gain vs. an environmental variable such as temperature; often expressed as %/°C or ppm/°C.

Gain Error. The difference between the actual and the ideal gain of a system.

General-Purpose Interface Bus (GPIB). IEEE 488 standard interface connecting peripheral devices, often sensors and programmable instruments, to a computer.

Gigabit Ethernet. Faster than the IEEE LAN standard transmitting at 10 Mbps; gigabit Ethernet transmits at 109 bps.

Gray Code. A digital code often used in absolute encoders where only 1 bit changes at a time between adjacent codes. This property limits ambiguity when the encoder is making a transition from one code to another.

Ground. A point that is assumed to be at a zero voltage potential. Ground in one system or location is not necessarily at equal potential to ground elsewhere. This can be a major cause of measurement error in a DAS system if not recognized and dealt with appropriately.

Ground Sense. A technique in which one input terminal of a differential input is used to measure the voltage of a remote ground to compensate for voltage differences between it and the ground at the DAS

Guard. A signal-shielding technique used with very high impedance sources, in which the shield is actively driven by the DAS or signal conditioner to compensate for errors resulting from leakage and capacitance.

Half-Flash A/D Converter. An ADC that determines its output code by digitally combining the results of two sequentially performed, lower resolution flash conversions; also called a subranging A/D converter.

Harmonic Distortion. A form of distortion in analog circuits in which harmonics (signals at multiples of the input frequency) are generated. Harmonic distortion can result from nonlinearities in the transfer function of the analog circuit. See **Total Harmonic Distortion.**

Hi-Pass Filter. A filter that allows only signal components above a specified frequency to be passed through.

High-Performance Parallel Interface Channel (HiPPI). An ANSI standard 100 MBps supercomputer channel.

IEEE 1394 Standard (Firewire). A high-speed, peer-to-peer peripheral serial bus.

Impedance. The equivalent resistance of an input or output. DAS systems should have much higher input impedances than the output impedances of the sensors to which they are interfaced, or gain errors will result.

Infinite Impulse Response (IIR) Filter A class of digital filters that are computationally very efficient, but which may become unstable if not designed properly.

Input Bias Current. The current drawn by the input terminal of a DAS. Excessive DAS input bias current can cause significant errors when high-impedance sensors are fed into that DAS.

Instrument Driver. A set of high-level software functions that control a specific DA board or GPIB or RS-232 instrument. Instrument drivers are available in several forms, ranging from a set of program-callable functions to complete virtual instruments.

Instrumentation Amplifier (IA or In Amp). A very high quality differential amplifier, often incorporating functions such as selectable gain and the ability to drive a guard.

Integral Nonlinearity (INL). The maximum deviation of the transfer function of a DAS from the ideal straight line. It is specified with offset and gain errors zeroed, and typically expressed in LSBs or as a percentage of F.S.

Integrating ADC. An ADC in which the input voltage is integrated over time. The different types of ADCs include single slope, dual slope, quad slope, and charge balancing. Integrating ADCs are commonly found in handheld digital voltmeters.

Intelligent Peripheral Interface (IPI). High-speed hard disk interface used with minis and mainframes to transfer data in the 10–25 MBps range.

Interference. Externally generated signals that combine with and obscure the signal of interest.

Internal Trigger. A trigger generated internally in a DAS, as by a pacer clock.

Interrupt. An external event that causes a computer to suspend its current operations and perform some other task. Interrupts allow a DAS to acquire data in the background while the host computer is busy doing other things.

Isolation. The condition of having no direct electrical path between two points. Isolation is commonly used for safety reasons in medical DASs.

Isolator. A device that passes a signal between two electrical circuits without providing any direct electrical connection. Isolators commonly use capacitive, magnetic, or optical techniques.

Java. Sun Microsystems' programming language. It is platform neutral—which means that the programmer need not be concerned with the workings of the processor or operating system—and incorporates a unique security strategy that prevents downloaded software components from corrupting the local computer environment. Programs developed in Java take the form of executable binary programs or are compiled into applets. Applets are stored in J-code, which can be executed only in a runtime system called the Java Virtual Machine.

JavaBeans. The architecture of Java that allows software components, or blocks of code, to be reused as parts of other programs.

Least Significant Bit (LSB). The binary digit with the smallest numerical weighting. The value of the LSB = FSR/2N, where FSR is the full-scale range and N is the number of bits.

Library. A collection of subroutines with some logical relation to one another, such as those providing the ability to interface to a DA board.

Lightweight Protocol (LWP). A communications protocol targeted at high-bandwidth (e.g., 80 MBps) and low-latency applications.

Linearity. The adherence of a device's response to a straight-line I/O relationship.

Linearization. The process of modifying a signal, either analog or digital, to compensate for the nonlinearities present in the source or in previous signal processing.

Low-Pass Filter. A filter that allows only signal components below a specified frequency to be passed through.

Millions of Instructions per Second (MIPS). A measure of processing speed for a DSP or conventional processor. While MIPS is a convenient way to roughly compare the performances of processors within the same family that have the same architectural features, it is largely useless for comparing fundamentally different types of processors.

Missing Code. A code that is not output for any input from an ADC. The cause is excessive differential nonlinearity.

Monotonicity. The characteristic of a DAC where increasing input codes result in increasing analog values. Nonmonotonicity may result when the differential nonlinearity of the DAC is greater than ±1 LSB.

Most Significant Bit (MSB). The binary digit whose value is equal to $^1/_2$ FSR. This code gives the largest incremental analog change possible by switching a single bit.

Noise. Any signal other than that of interest. Some noise is intrinsic to the system being measured and to the DAS itself; other noise is the result of interference.

Notch Filter. See **Band-Stop Filter.**

Nyquist Limit. The theoretical minimum sampling rate required to reconstruct an analog signal. The Nyquist theorem states that to reconstruct an analog signal, the signal must be sampled at a rate at least twice that of the highest component in that signal ($2f_0$). For practical applications, sampling should be much faster than the Nyquist limit, and active steps must be taken to ensure that high-frequency signals approaching the Nyquist limit are not presented to the ADC where they could cause aliasing. See **Anti-Aliasing Filter.**

Pacer Clock. A timer on a DA board that periodically triggers the ADC to perform a conversion without the computer's direct supervision.

Parallel Port Interface. A popular method of connecting external DASs to a PC via the printer (parallel) port.

PCMCIA. Personal Computer Memory Card International Association, a nonprofit trade organization. The standard itself is properly called PC Card. An I/O port present on many portable computers into which options such as modems, disk drives, and DA boards may be attached.

PC/104. A standard that defines a compact, modular form-factor version of the PC bus on 3.6 in. by 3.8 in. cards. It is used in embedded computer systems.

Pipelined ADC. A form of high-speed A/D conversion in which each conversion is performed as a sequence of subconversions, with each part of the sequence handled by a separate piece of hardware. This provides a high rate for successive conversions, typically 1 per clock cycle, but any given conversion will require multiple clock cycles between the time when the analog input was sampled and the time the data become available.

Post-Triggering. A technique used on DA boards to acquire a programmed number of samples after a trigger event has occurred.

Pre-Triggering. A technique used on DA boards to keep a continuous buffer filled with data so that when trigger conditions are met, the sample includes the data leading up to the trigger condition.

PUSH. A service in which the Internet becomes a proactive provider of information: the user is shipped a daily briefing on identified topics of interest with hot links to web sites and other pages.

Quantization Error. The inherent uncertainty in digitizing an analog value due to the finite resolution of the conversion process.

Radio Frequency Interference (RFI). Interference that has frequency components in the radio frequency range (>100 kHz).

Real-Time Processing. A procedure in which the results of an acquired and computed value can be used to control a related physical process in real time.

Reference. A stable source for a physical quantity, such as voltage, used by a DAS to maintain measurement stability and repeatability.

Repeatability. An instrument's ability to produce the same output repeatedly at different times under identical conditions.

Resolution. The smallest detectable change in a measurement. Resolution can be stated as a % of F.S. but is more commonly expressed as a number of bits. A 12-bit DAS has 2^{12} possible output states, giving it a resolution of 1 part in 4096.

Sample-and-Hold (S/H). A circuit that acquires and stores an analog voltage for a specified period of time.

Sampling ADC. An ADC with an integral sample-and-hold circuit.

Scalable Coherent Interface (SCI). The ANSI/IEEE 1596 communications standard, featuring module-defined signals, connector, and power for operating a linked speed of 1000 MBps.

Self-Calibration. A property of a DAS that has an extremely stable onboard reference and calibrates its own ADC and DAC circuits without manual adjustments by the user.

Sensor. A device that converts latent information about the environment into a more convenient or understandable form.

Settling Time. The time elapsed between the application of a F.S. step into a circuit and the time that the output enters and remains within a specified error band around its final value.

Shield. A conductive barrier surrounding signal conductors for the purpose of excluding or attenuating externally generated interfering signals.

Signal Conditioning. A set of techniques for processing an analog signal from one form into another more suitable for processing by a DAS. Amplification, linearization, temperature compensation, filtering, and isolation are all examples of signal conditioning.

Signal-to-Noise Ratio (SNR). Ratio of the signal of interest to the intermixed noise expressed in decibels. SNR = 20 log (rms signal/rms noise).

Simultaneous Sample-and-Hold (SS/H). A feature in a DAS where each input channel has a separate S/H circuit. This allows the DAS to sample all inputs truly simultaneously, as opposed to scanning them in quick succession.

Simultaneous Update. A feature in a DAS whereby all DACs are loaded with new values sequentially, but commanded to update their outputs simultaneously.

Single-Ended. A circuit with a single signal conductor, referenced to system ground.

Slew Rate. The maximum speed, expressed in volts per second, at which a signal can change.

Small Computer System Interface (SCSI). An interface for up to seven peripherals; actually, an 8-bit bus interface for up to eight devices, of which the host adapter constitutes one device.

Software Trigger. A programmed event, initiated by a program or subroutine, that triggers another event such as DA.

Span. The algebraic difference between the upper and lower limits of an input range; expressed in the same units as the device range.

Spectrum. A data set containing the frequency-domain representation of a time-domain signal; obtained as the result of applying a Fourier transform to a time-domain signal.

Stability. The ability to maintain a constant output during the application of a constant input.

Status Register. A readable register on a DA board that indicates the status of that board, such as whether it is ready to perform an A/D conversion, is busy, or has data ready from a previous conversion.

Subranging A/D Converter. See **Half-Flash A/D Converter.**

Subroutine. A short program that is called by the main program to perform a specific function. Subroutines make code simpler to write and maintain by hiding unnecessary low-level details from the programmer.

Successive Approximation A/D. An ADC that sequentially compares a series of binary weighted values with an analog input signal to produce a proportional output digital word.

Supervisory Control and Data Acquisition (SCADA) A common PC function in process control applications where PLCs perform control functions but are monitored and supervised by a PC.

Time Stamp. Information indicating the real time at which one or more measurements was acquired by a DAS.

Total Harmonic Distortion (THD). The ratio of total rms signal due to harmonic distortion to the overall rms signal; usually expressed in decibels. THD = 20 log (rms distortion/rms signal).

Track-and-Hold (T/H). A sample-and-hold circuit in which the output continuously tracks the input except when explicitly commanded to hold.

Tracking A/D Converter. An ADC in which the output continuously tracks the input. Tracking ADCs offer very high resolutions and conversion rates for signals that do not vary too quickly for them to track.

Transducer. A device that converts information about the environment or internal state of a system from one form into another.

Transfer Function. The input to output response characteristics of a device, expressed either mathematically or graphically.

Transmitter. A device that converts the output of a sensor into a form more suitable for communication to another system.

Unipolar. An input or output in a DAS that supports either positive or negative signal magnitudes, but not both.

Universal Serial Bus (USB). A contemporary high-speed serial bus standard for PC peripherals.

Virtual Instrument. A simulation of classical instrumentation in software designed to control a DAS.

Voltage-to-Frequency (V/F) Converter. A device that converts an input voltage into a periodic waveform output with a frequency proportional to the input voltage.

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